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ARTICLES

The Wear of Farm Tools 291
H. BORNSTEIN

The Microscopical Constituents of Steel 297
ALBERT SAUVEUR

The Nature of Inclusions in Cast Iron 299
F. W. SCOTT AND T. L. JOSEPH

Carbonized Nickel for Radio Tubes 303
T. H. BRIGGS

Some Useful Probability Tables 309
H. V. JOHNSON

Cupaloy in the "Time Capsule" 311
P. H. BRACE

Industrial Uses of Titanium—II 314
GEORGE F. COMSTOCK

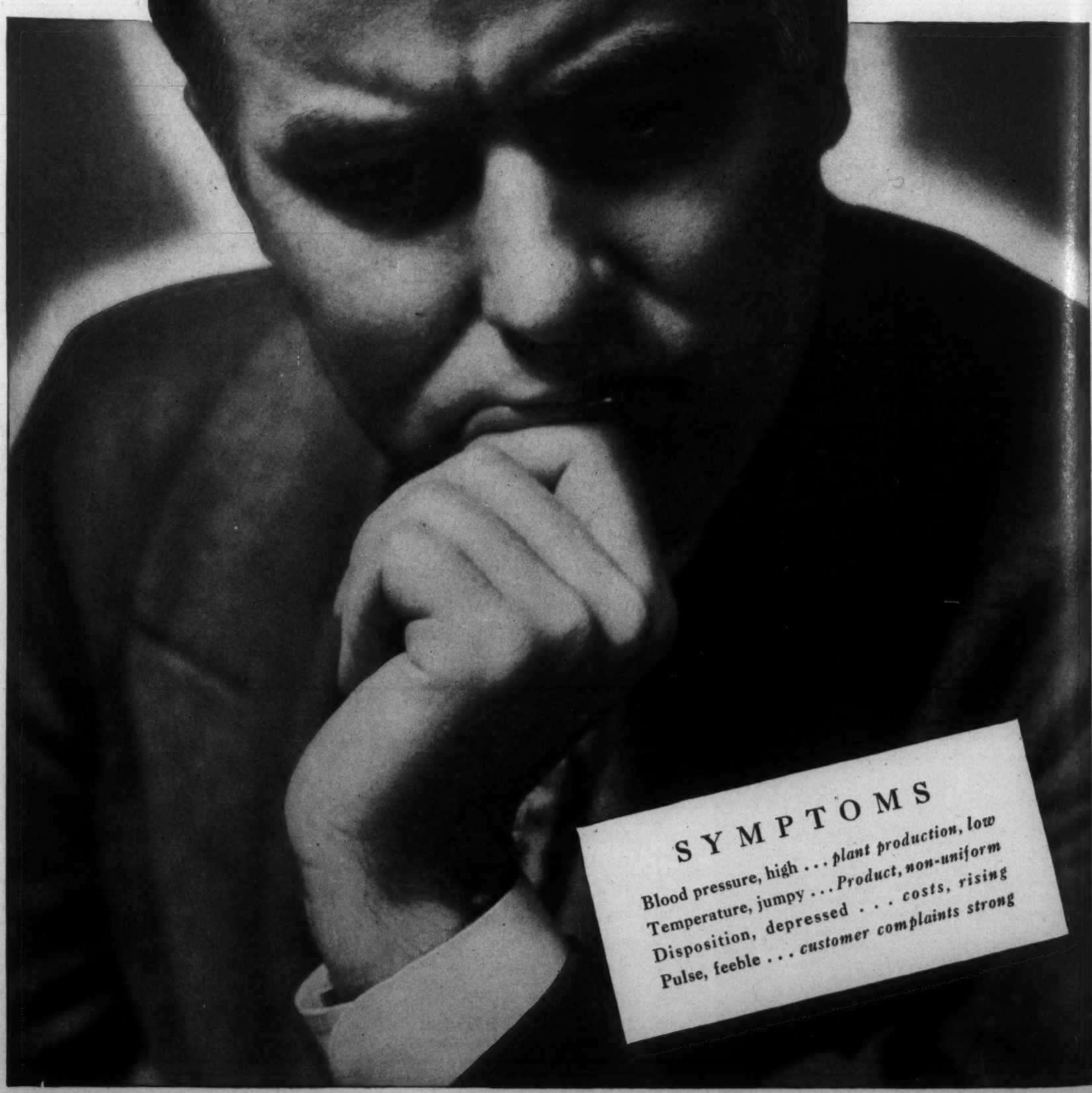
Honesty in the Foundry Business—I 319
HAROLD J. ROAST

Highlights . . . . . A 17
Editorial . . . . . A 19
New Equipment and Materials . . . . . A 23
Current News Items . . . . . MA 685
Book Reviews . . . . . MA 688
Manufacturers Literature . . . . . MA 690

METALLURGICAL ABSTRACTS

Ore Concentration . . . . . MA 638
Reduction . . . . . MA 639
Melting, Refining and Casting . . . . . MA 640
Working . . . . . MA 646
Heat Treatment and Heating . . . . . MA 648
Welding and Cutting . . . . . MA 655
Finishing . . . . . MA 659
Testing and Control . . . . . MA 662
Metallography . . . . . MA 666
Properties and Applications . . . . . MA 676
Corrosion and Wear . . . . . MA 679
General . . . . . MA 683

Works Manager


SYMPTOMS
Blood pressure, high . . . plant production, low
Temperature, jumpy . . . Product, non-uniform
Disposition, depressed . . . costs, rising
Pulse, feeble . . . customer complaints strong

The Wear of Farm Tools

by H. Bornstein

Director, Testing and Research Laboratories
Deere & Co., Moline, Ill.

Plowing with a 4-Bottom Moldboard Plow.

This article offers the reader an expert appraisal of a subject that is easily grasped. The author has refrained from going into details that would distract the reader's attention. Power farming, as developed in recent years, has introduced many problems of wear, due to greater speeds and severer service. Hence design cannot be separated from the metallurgy, and the best results are obtained by close cooperation of the designer and the metallurgical engineer.—The Editor.

THERE ARE VARIED PROBLEMS in connection with the wear of farm tools. Many types of wear are included and each case must have individual attention in connection with design, selection of materials, and treatment.

A common type of wear is abrasive wear without lubrication, such as in plow bottoms, plow disks, and cultivator shovels.

Plow Bottoms

A plow bottom consists of a plow share and a moldboard. The plowshare cuts the furrow while the function of the moldboard is to turn the furrow. The plowshare must have good cutting properties, while the moldboard must have good shedding or scouring properties.

Considering plowshares from the standpoint of material and treatment, there are three usual types. These are (1) hardened, soft center or three-ply steel, (2) unhardened high carbon steel, and (3) chilled cast iron. The selection of the type of share depends largely upon the conditions of plowing.

Where scouring is a problem and also where stony ground must be taken into consideration, soft center steel has found considerable favor. It has been in use for many years and is popular today. The three layers of steel are of approximately equal thickness with the two outside layers of high carbon (approximately 1.0%) with the center layer of low carbon (about 0.10%) steel. Such a plowshare is hardened usually in a brine solution so that the surface is definitely file-hard. It is quite essential that the surface of the plowshare be free from "soft spots."

The purpose of the soft center steel is to furnish a material which will harden to file hardness and yet retain a fair amount of ductility, due to the soft core. Single-ply high carbon steel, hardened in brine or water to obtain file hardness would crack or break in the quenching, or subsequent, operations.

A number of attempts have been made during a period of years to substitute a single-ply steel for the three-ply steel. About 15 years ago, we made up some plowshares of an alloy steel having a carbon content of about 0.5%.

Cultivating Soya Beans.

These shares hardened satisfactorily in oil and we were very much pleased with the results of laboratory tests. These shares were practically as hard as shares made from soft center steel, but were considerably tougher. Also, the fracture was much finer and very much like tool steel. We put these shares out into service and we found that they were not as satisfactory as soft center steel in reference to wear resistance. We did not have the abrasion resistance such as we have found in the three-ply steel.

Later on, we found that it was probably the carbon content which was the controlling factor in the wear of these shares. Tests made with shares of various steels indicated that the carbon content was a controlling factor in the matter of wear.

Since that time, there have been a number of other attempts made to substitute an oil hardening alloy steel for a three-ply steel. At the present time, several alloy steels are being tried out experimentally and these have carbon contents in the neighborhood of 0.70 per cent. This carbon content may be sufficiently high so that the wear resistance may be comparable with that secured from a hardened soft center steel.

In farm tools, such as plowshares, it is not possible to divorce wear resistance from shock resistance. Frequently, it is necessary to have a material which not only can resist abrasion, but will also withstand considerable shock, such as encountered when the share hits stones or rocks.

Material in Plowshares and Moldboards

A popular share material is a high carbon steel containing about 0.8 per cent carbon. This is a single ply steel, but is usually not heat treated. In some cases, only the point of the share is subjected to a heat treatment. Where the scouring conditions are not difficult, the farmer frequently finds this type of plowshare to be more economical than the soft center share.

Another type of share that finds favor in many parts of the country is a cast iron share. The cutting edge is chilled so that we have a white iron edge. This gives increased hardness and also increased wear resistance. Because white iron does not have a great deal of shock resistance, this type of share cannot be used under same conditions in stony ground. Chilled cast iron shares are frequently chosen because they are low in price compared with steel shares. The chilled iron shares are best adapted to sandy soils. The composition is controlled to give a chilled cutting edge and a pearlitic matrix in the body of the share.

What has been said about plowshares is pretty much true about moldboards. A soft center share is usually used with a soft center moldboard. It is important here to have a file-hard surface in order to obtain a good scouring.

Some moldboards are made in a single-ply high carbon steel. These are usually used in connection with high carbon steel shares. Frequently, however, a high carbon steel share is used in connection with the soft center moldboard.

Cast iron moldboards are used to a considerable extent. These are usually chilled over the entire face, so as to obtain great surface hardness and good scouring properties. In connection with scouring, it has been our experience that a chilled iron moldboard is superior in scouring properties to unchilled white iron moldboards of equivalent hardness.

Wear of Plowshares

There are some peculiar problems that arise from time to time in connection with wear of plowshares. About a

dozen years ago, we were supplying a plowshare made of rolled high carbon steel for certain territories in South America. We were advised that these shares did not wear as well as some other shares sold in that locality. An examination of these shares showed them to be low carbon steel castings. We then supplied them a low carbon steel casting for plowshares and we were told that the results were satisfactory. However, we cannot understand, even to this day, why the higher carbon steel share did not give satisfactory wear.

Plow Disks and Harrow Disks

For many years, plow disks and harrow disks were made of a high carbon steel, about 0.85 per cent carbon, and were not heat treated. The results were seemingly satisfactory until one manufacturer brought out a heat-treated disk. Immediately there was a shift in demand so that heat-treated disks were asked for and supplied. The present carbon steel heat-treated disk is usually quenched and drawn to a Brinell hardness in the neighborhood of 400. When the disks were not heat treated, the Brinell hardness averaged somewhat higher than 200.

Field tests indicate that the heat-treated disk does have better wear resistance than the disk which was not heat treated. However, the principal advantage of the heat-treated disk is increased strength and ductility. Disks frequently have to be used under very severe conditions and in stony ground. Consequently, the disk which can withstand abuse is said to "wear better" than a disk which cannot resist such abuse. What is meant by "wear" here is a combination of wear and toughness, rather than pure wear.

In territories where the conditions are extremely severe, alloy steel disks have found some favor, due to the increased toughness over carbon steel disks of the same hardness. In respect to wear, our experience is that the carbon steel disk wears at least as well as the alloy steel disk.

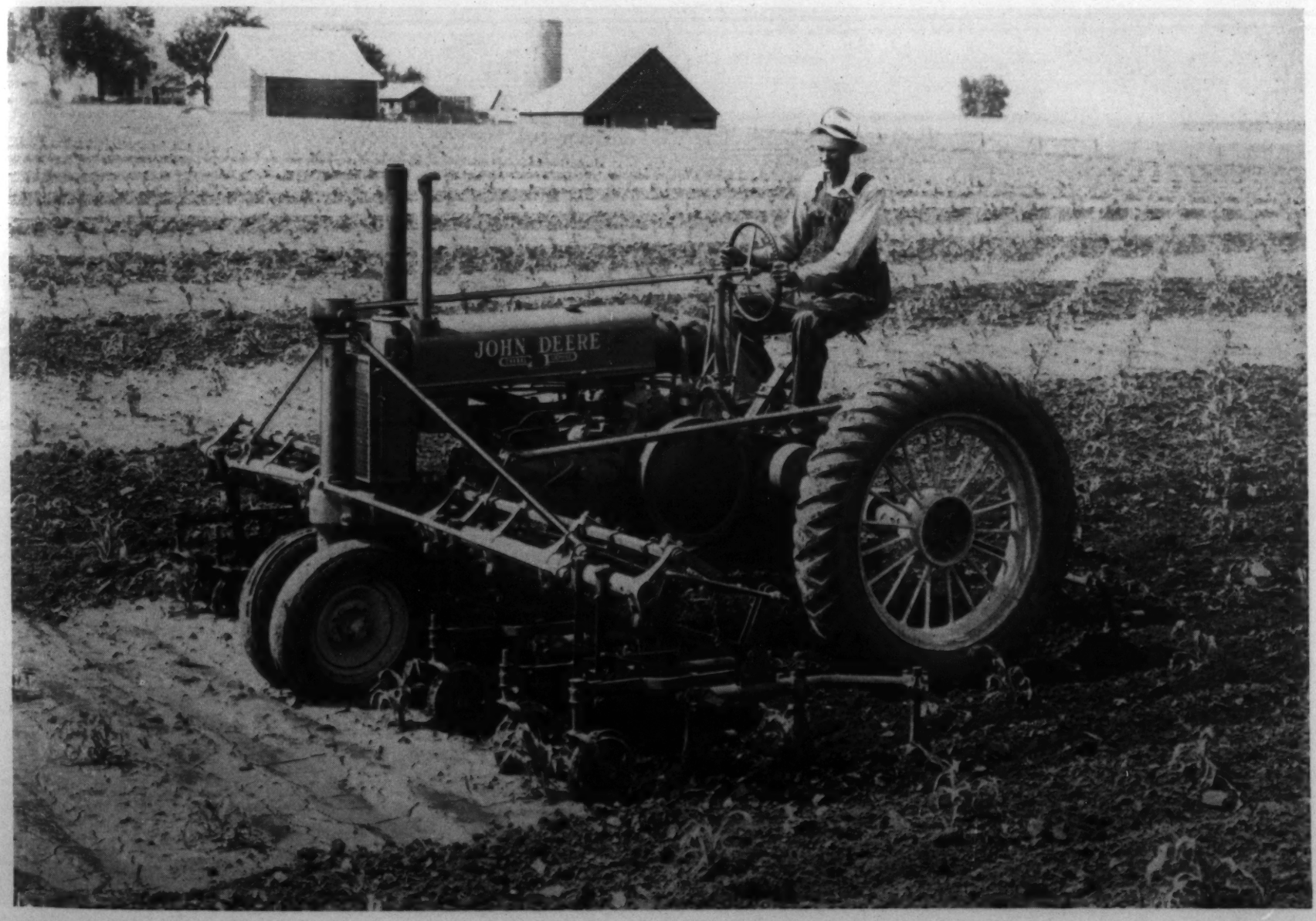
Some years ago, an alloy steel disk of low carbon content was put on the market. This disk was heat treated to the usual range of Brinell hardness, about 400, and it was quite tough. However, experiments indicated that it did not wear as well as a higher carbon disk and for this reason the use of this particular steel was discontinued. This indicated again the importance of carbon in controlling wear resistance. We have had cases where low carbon alloy steel disks, heat treated to 400 Brinell, did not wear as well as a carbon disk with carbon content of 0.90 per cent, not heat treated, with a Brinell hardness in the neighborhood of 200.

Our experience with wear on plow bottoms and disks can be summarized by stating that for the same kind of steel, an increase in hardness usually means an increase in wear resistance. However, for the same hardness, an increase in carbon resulted in better wear resistance.

Cultivator Shovels

Cultivator shovels are used extensively and are replaced frequently, due to wear. A wide range of compositions

Cultivating Corn with a 4-Row Cultivator.



are used by the various manufacturers. Our experience indicates that a heat-treated high carbon steel shovel gives the best results in regard to wear resistance and resistance to abuse.

We have tried many laboratory tests in an effort to secure a correlation between laboratory tests and wear in service. For the most part, these laboratory tests failed to give us such a correlation. A few years ago, we made some tests on a number of steels using the Brinell abrasion testing machine. These test results came closest of all the laboratory tests to conforming with results in the field.

Wear of Chain and Sprockets

Besides having abrasive wear, unlubricated, such as we have in plowshares, disks, etc., we have another type of unlubricated wear such as a chain on a sprocket. The amount of wear on the chain and on the sprocket depends first on design and second, upon the materials and treatments used. Quite frequently, steel chain is used and we have had conditions of severe wear on cast iron sprockets. In many cases, this has been remedied by chilling the sprocket so as to have a white iron surface.

In many cases malleable chain is used with satisfactory results. Under certain conditions, we obtain too much wear on the malleable chain. One means of correcting such a condition is the use of pearlitic malleable, which has a higher hardness than the normal malleable cast iron.

Another type of wear experienced in farm tools is where we have lubricated sliding surfaces. An example of this is the cast iron piston and cast iron cylinder in a tractor. We made a series of laboratory and field tests a number of years ago and determined that an increase in the Brinell hardness of the cylinder bore gave us increased wear resistance. A change was made in the foundry practice by introducing the use of alloys, so as to secure the desired hardness without sacrificing machinability. A pearlitic iron was found to be desirable.

Cylinder Liners & Sleeves in Tractors

In many farm tractors, cylinder liners or sleeves are used. Alloy cast iron is frequently applied and in a number of cases, the liners are heat treated by quenching and drawing. This results in a Brinell hardness of about 450 and a substantial increase in wear resistance.

The conditions in a tractor are usually more severe than in an automobile because of the prevalence of dust which may get into the engine. Considerable work has been done on tractor air cleaners in order to reduce the amount of dust entering the engine to a minimum. However, it is well to point out that the presence of this dust in the engine tends to act as an abrasive and accelerates wear. Much has been done to decrease wear in cylinders through better finish on the surface of the cylinder. The mechanical condition of the surface is important in reducing wear.

In farm tools, we have many bearings which are sub-

Plowing with a 5-Disk Plow.

Tilling Stubble with a 11-Disk Tiller.

jected to dusty conditions. In recent years, the desirability of excluding dust from the bearings has been recognized and decided efforts have been made in this direction. It was found that in many cases, even when the bearing was lubricated, the dust would act as an abrasive and the bearing would wear out rapidly.

Bearings in Farm Tools

There are many types of bearings used in farm tools, ranging from a non-lubricated or partially lubricated gray iron bearing to a completely lubricated high grade roller bearing such as is used in automotive practice. The type of bearing chosen depends upon the service condition and good design requires the selection of the lowest cost bearing which will do a satisfactory job.

In many cases for light service, bearings are made of cast iron and are cast to size, so as to eliminate machining. Frequently, the bearings are chilled so as to obtain a smoother surface, hold to close dimensions, and secure better wear resistance.

During the past few years an oil impregnated, porous bronze bearing (a product of powder metallurgy) has had many applications in automotive work. It has also found favor for bearings in farm tools, particularly where the wear or scoring of shafts is a problem.

In all these bearing problems, the designer has realized the importance of keeping the dust out of the bearing. To check up on the design, laboratory tests have been set up, so that the assembly may be run under very dusty conditions. After definite periods of time the bearings are examined to note the presence or absence of dirt and the amount of wear.

Gears also present wear problems. In farm tools the range is from gray iron gears cast to size to carburized and hardened alloy steel gears machined to close tolerances. Again the particular application determines the material and treatment. For cast iron gears we have frequently made alloy additions which increase hardness and improve the structure. The result has been better wear resistance.

Hard Facing

A discussion of wear on farm tools would be far from complete without mentioning the interesting subject of "hard facing." Many materials are on the market for the hard facing of parts which are subjected to considerable wear. These materials are usually applied by means of an acetylene torch. In many cases, the hard faced part gives a good account of itself, due to decreased wear and also maintenance of cutting edge. In other cases, the value of the hard facing apparently is more than offset by the increased cost of application. Much experimental work is now being done on the hard facing of many tools and a variety of materials so that the picture will be considerably clarified within the next few years.

Power farming, which means the use of the tractor, has introduced many problems of wear in farm tools. Speeds are greater and the service is more severe. As a result, more attention is being given to the selection of materials and their treatment. The design cannot be separated from the metallurgy; so the best results are obtained by close cooperation of the designer and the metallurgist.

Courtesy: Jones & Laughlin Steel Corp.

A Zeiss Microscope in the Metallographic Laboratory of J & L's New Research Dept.

The Microscopical Constituents OF STEEL

by Albert Sauveur

FURTHER comment and light on the controversy over the proper nomenclature for the microscopical constituents of steel is given space in the following contributions by Dr. Albert Sauveur: A short article presenting more explicitly his views on the microscopical constituents of steel in response to a number of requests and a discussion of the article by Vilella and Cooper in our September issue entitled "Significance of the Terms Troostite and Sorbite," page 223. The first contribution on this subject was entitled "Wanted: An International Committee on Nomenclature", by Dr. Sauveur, *Metals and Alloys,* June, 1938, page 137.—The Editors.

IN VIEW OF THE INTEREST recently shown in the subject of the Nomenclature of the Microscopical Structures of Steel and of several requests for a more explicit expression of my opinion, I venture the following remarks:

Transformations

Austenite is a solid solution of carbon in gamma iron. The transformation of austenite into an aggregate ot ferrite and cementite is due to the allotropic transformation of gamma iron into alpha iron.

If gamma iron did not undergo an allotropic transformation, austenite would not transform.

As alpha iron is unable to retain any appreciable amount of carbon in solid solution, and as the transformation of gamma iron into alpha iron must *necessarily precede* the formation of carbide particles, it follows that, for a fleeting moment at least, a solid solution of carbon in alpha iron exists which is excessively supersaturated and from which carbon is immediately rejected in the form of cementite particles which at first *must be submicroscopic.*

This, in my opinion, corresponds to the martensitic stage.

It is immediately followed by a gradual and progressive agglomeration of these minute particles, which also evidence a tendency to align themselves along certain crystallographic planes and which eventually constitute the structure of pearlite.

For convenience, various degrees of agglomeration have been designated as troostite and sorbite, somewhat as we use for convenience and clarity of speech the expressions babyhood, childhood, and manhood.

When the alloy is hypoeutectoid, the transformation of austenite is preceded, when time permits, by the rejection of free ferrite. Rapid cooling, however, may prevent this rejection in part at least, when some "excess" ferrite will be found included in the troostitic or sorbitic structures.

Size of Carbide Particles

That there is a *gradual* increase in the size of the carbide particles of cementite is proven by the colorimetric determination of carbon, when it is found that the "color" carbon is minimum in martensite and increases progressively through troostite, sorbite, and pearlite. In spheroidized pearlite the percentage of color carbon is greater still, as it should be.

When martensite, considered as an aggregate of ferrite and of extremely small (possibly submicroscopic) particles of cementite, is reheated (tempered), those particles agglomerate, this agglomeration being progressive and giving rise to structures which have also been designated, unfortunately, as troostite and sorbite. These types of sorbite and troostite differ from the sorbite and troostite resulting from the cooling of austenite in never exhibiting any tendency towards the formation of a lamellar structure.

This is why it would be advisable to distinguish between them, in calling the former "lamellar" and the latter "granular."

It is claimed by some that the structures or constituents, which heretofore have been called sorbite and troostite, are in reality pearlite of different degrees of fineness, sorbite being fine pearlite and troostite still finer pearlite, quite regardless of the carbon content.

Clarification

To clarify—steel containing 0.40 per cent carbon and made sorbitic or troostitic by suitable rates of cooling from the austenitic range would be, in their opinion, in reality, pearlitic. Were it not so, it would be necessary to conceive the existence of pearlite containing but 0.40 per cent carbon, or even less.

Pearlite would cease to be the structure of the iron-car-

bon eutectoid. Indeed, the very term eutectoid, suggesting a eutectic-like constituent, would lose its significance.

Such contention is based on the lamellar appearance of sorbite and troostite when examined under very high magnification. Returning to our 0.40 per cent carbon alloy made sorbitic or troostitic, I believe that it is only in isolated spots that the lamellar structure is detected, and I believe that in these spots eutectoid composition has been approximately attained by rejection of excess ferrite.

Some Definitions

With these considerations in mind, I would define some of the microscopical constituents or structures of steel as follows:

(1) *Austenite:* A solid solution of carbon in gamma iron, stable above the thermal critical range of iron-carbon alloys.

(2) *Martensite:* An aggregate of ferrite and extremely small (possibly submicroscopic) particles of cementite. To obtain it, the iron-carbon alloy should be cooled from a temperature higher than its thermal critical range slowly enough to permit its formation and quickly enough to prevent its transformation through agglomeration of the carbide particles. The cooling of iron-carbon alloys, however, cannot be drastic enough to prevent the transformation of the major part of austenite into martensite.

(3) *Lamellar troostite:* An aggregate of ferrite and of particles of cementite of larger size than those present in martensite, and exhibiting under high magnification a tendency to form a lamellar structure. Lamellar troostite is obtained by cooling iron-carbon alloys from a temperature higher than their thermal critical range slowly enough to permit its formation and quickly enough to prevent further agglomeration of the cementite particles, as, for instance, by quenching in oil from the austenitic range steel bars of suitable carbon content and suitable dimensions.

(4) *Lamellar sorbite:* An aggregate of ferrite and of cementite particles larger in size than the particles found in lamellar troostite and exhibiting, when examined under high magnification, a marked tendency to form a lamellar structure. To obtain this structure, the iron-carbon alloy should be cooled from a temperature higher than its thermal critical range slowly enough to permit its formation and rapidly enough to retain it—as, for instance, by cooling in air from the austenitic range steel bars of suitable carbon content and suitable dimensions.

(5) *Pearlite:* The structure of the iron-carbon eutectoid. It contains in the vicinity of 0.85 per cent C and consists of parallel plates or lamellae, alternately of ferrite and cementite. To obtain it, the iron-carbon alloy should be cooled slowly through its thermal critical range—as, for instance, with the furnace in which it was heated.

(6) *Granular troostite:* An aggregate of ferrite and cementite particles resulting from the heating of martensite to temperatures generally not in excess of 400 deg. C.

(7) *Granular sorbite:* An aggregate of ferrite and cementite particles larger than those present in granular troostite and resulting from the heating of martensite to temperatures generally in excess of 400 deg. C. but not above 700 deg. C.

Comment on the Article by Vilella and Cooper

By Dr. Sauveur

I SHOULD LIKE to be permitted to comment briefly on some of the conclusions drawn by J. R. Vilella and L. R. Cooper in their interesting article, "Significance of the terms Troostite and Sorbite," published in METALS AND ALLOYS for September, 1938, p. 223. I have more especially in mind the following paragraph:

> The foregoing discussion of the Report of the Committee on Nomenclature may be regarded by some as a criticism of something long forgotten and out of date. Yet, the fact remains that this report and its underlying assumptions are the basis of the present nomenclature. Any effort to perpetuate the use of the terms "Sorbite" and "Troostite" to denote some indefinite subdivisions of the lamellar series of structures is a tacit admission of the reality of discontinuities in the structures of steel for which there is no positive metallurgical or microscopic evidence. Likewise, the use of these two terms to denote granular and lamellar structures implies identity when there is in fact real difference.

It is, of course, perfectly proper for the authors to consider the report of the 1910 Committee on Nomenclature as "something long forgotten and out of date." I hold, however, that so long as the matter has not again been considered by a responsible international committee, that report cannot be discarded on the recommendations of a small group of men. For their own satisfaction they may do so, but they can hardly expect their views to be generally adopted by others.

It is unnecessary again to remind those interested that all students of metallography agree that there should be a way of distinguishing between the constituents Troostite and Sorbite resulting from the decomposition of Austenite and the constituents of the same names resulting from the tempering of Martensite. It is why the terms "primary" and "secondary" or "lamellar" and "granular" have been proposed. This is a simple way out of the difficulty and removes all possibility of confusion.

When the authors state that "any effort to perpetuate the use of the terms Sorbite and Troostite to denote some indefinite subdivision of the lamellar series of structures is a tacit admission of the reality of discontinuities in the structures of steel for which there is no positive metallurgical or microscopic evidence," they seem to ignore the fact that neither Osmond nor his followers ever believed in the existence of such discontinuities. Several pages of this journal could be filled with quotations to prove it, but a single statement by Osmond should suffice. He wrote in 1895:

> The existence of these forms of transitions, both in theory and in fact, is as certain as the existence of an orange shade between red and yellow in the solar spectrum. The operation of dividing a continuous series, however, is necessarily an arbitrary one, and the number of divisions will vary with different points of view . . . Troostite represents a transition form which approaches more than Martensite the normal state of equilibrium at the ordinary temperature . . . Sorbite approaches still more the condition of stable equilibrium at ordinary temperature.

To do away with these extremely useful terms on the ground that no sharp lines of demarcation exist between the structures they represent would be as wise and justified as to do away with the terms babyhood, childhood, and manhood when dealing with the growth of man, on the ground that we have here a complete absence of discontinuity and that, at every stage of his physical development, man has two legs and two arms.

By proposing to retain the term Sorbite for the structure resulting from the tempering of Martensite, the authors appear inconsistent, for it would be an admission on their part that a discontinuity exists between Martensite and Sorbite.

THE NATURE OF

Inclusions in Cast Iron

by F. W. Scott and T. L. Joseph

Instructor and Professor of Metallurgy Respectively, University of Minnesota, Minneapolis, Minn.

This article is the second in a series dealing with a study of the oxide inclusions or non-metallics in gray irons and their relation to graphitization. The first article, by Professor Scott, entitled "The Extraction of Oxide Inclusions in Gray Iron—Electrolytic Iodine Method," was published in the July and August issues.

The present contribution deals with the analysis of the oxides. The third article will discuss the effect of caustic soda treatment upon the oxide analysis, graphite refinement, and physical properties.

The entire research should ultimately result in better quality cast irons.—The Editors.

IT IS WELL KNOWN that the engineering properties of cast iron depend upon the continuity of the matrix, as well as upon the character of the matrix itself. The degree of continuity depends upon the form and distribution of the graphite flakes. Many puzzling phenomena have arisen because the well-known variables such as carbon and silicon content and the rate of cooling have not afforded an adequate explanation of the response of the graphite to melting and casting. Gillett[1] has summarized many cases in which the effect of some obscure factors upon graphite structure has persisted through remeltings.

The action of solid particles in initiating crystallization in super-saturated solutions has attracted attention to the effect that inclusions might have upon graphite growth and distribution. In a detailed consideration of the mechanism of graphitization, Bolton[2] recently reviewed various inclusion theories, such as the graphite nuclei hypothesis of Piwowarsky, Hannemann and their co-workers, the silicate slime hypothesis of Von Kiel and associates, and the formation of ineffective fluid inclusions as proposed by Norbury and associates. Thus far the evidence that inclusions influence graphite structure has been indirect. No direct correlations of the amount, composition or degree of dispersion of inclusions and graphite structure have been presented. Microscopic studies have not been pursued extensively because the inclusions have been thought to be submicroscopic in size. If associated with graphite, the difficulty of retaining inclusions in polished specimens is also obvious.

Few data are available concerning the nature and analysis of oxides in foundry iron. One of the writers[3] has reported the results of a study of the oxides in basic pig iron. A more recent report by one of the authors[4] gives the results of a study to determine whether wide variations in four of the major metalloids affect the amount or composition of the oxides in cast iron. The results indicated the electrolytic method developed by one of writers provides a means of studying the oxides in cast iron. A few results have been published showing that cast iron may contain considerable amounts of total oxygen (combined form). These determinations, made by the hydrogen reduction or vacuum fusion methods, do not however afford any information regarding the manner in which the oxygen occurs. Using the fractional vacuum fusion method, Reeves[5] reported a total oxygen of 0.047 per cent, present largely as FeO and MnO.

With a promising method available, the first work undertaken was to examine iron produced in a number of foundries to establish a sort of base line as to the amounts of oxides normally in commercial iron. The oxides were extracted from large solid pieces of gray iron by the electrolytic iodine method.[4] In view of the likely random distribution of inclusions and possible accidental inclusions, two methods of sampling were tried:

(1) Two discs about 3/16 in. thick were cut from the mid-section of test bars 18 in. long and 1.2 in. in diameter. The test bars were cast in dry sand molds. Both discs were extracted simultaneously, giving a composite sample of 50 to 75 grams.

(2) Three coupons, 2 x 3/4 x 3/16 in. were cut from a rectangular chill bar cast in the split graphite mold shown in Fig. 1. The mold was made by splitting a 14-in. length of a 3-in. graphite electrode along the longitudinal axis. A rectangular opening 3/4 x 2 x 12 in. was made in one half of the electrode. As indicated by the chill bar on the right,

Table 1. Chemical and Oxide Analyses of Gray Irons

Foundry	Furnace Used	Mold Used	Chemical Analysis					Oxide Analysis			
			Total C	Si	Mn	P	S	SiO_2	MnO	FeO	Calc. O_2
A 1	Cupola	Sand	3.52	2.16	0.46	0.439	0.081	0.0145	0.0002	0.0048	0.0088
A 2	Cupola	Sand	3.52	2.31	0.47	0.420	0.088	0.0125	0.0002	0.0050	0.0077
A 3	Cupola	Sand	3.38	2.35	0.50	0.447	0.091	0.0083	0.0001	0.0041	0.0053
A 4	Electric	Sand	3.36	2.13	0.47	0.421	0.068	0.0102	0.0007	0.0032	0.0063
A 5	Electric	Sand	3.32	2.17	0.43	0.458	0.078	0.0253	0.0001	0.0029	0.0141
A 6	Electric	C	3.18	2.12	0.46	0.442	0.067	0.0056	0.0002	0.0050	0.0041
A 7	Electric	C	3.28	2.25	0.43	0.462	0.086	0.0040	0.0002	0.0074	0.0038
B	Cupola	C	3.47	2.29	0.50	0.525	0.072	0.0061	0.0005	0.0117	0.0059
C 1	Cupola	C	3.51	2.29	0.54	0.289	0.084	0.0038	0.0003	0.0030	0.0027
C 2	Cupola	C	3.50	2.40	0.52	0.234	0.077	0.0038	0.0004	0.0033	0.0028
C 3	Cupola	C	3.57	2.36	0.52	0.305	0.080	0.0063	0.0003	0.0061	0.0047
D	Cupola	C	3.40	1.51	0.86	0.186	0.082	0.0062	0.0003	0.0035	0.0041

one coupon was cut 1½ in. from the top of the chill bar, a second 1½ in. from the bottom and a third from the middle of the bar. Each of the three coupons was extracted separately and the average results used for the amount and analysis of the oxide.

Samples were obtained at different times from four foundries, designated in Table 1 by letters. Part of the iron was melted in cupolas and a part of it in electric furnaces as indicated in the table. The samples represent several types of melting practice on plain cast iron. The chemical analyses and oxide analyses of the irons are shown in Table 1.

Discussion of Results

It is apparent that a small amount of sand was washed into the sand cast samples, as all such samples contained higher percentages of SiO_2 than any of those cast in the graphite mold. Special precautions were taken to grind the surface of the tests before their extraction. The results should accordingly represent the metal itself and not any sand in the skin of the casting. The tests poured in the graphite mold are remarkably constant in silica content, varying from 0.0038 to 0.0063 per cent. These figures compare very favorably with the cleanest steels deoxidized with silicon.

The MnO is present in very small amounts, the range being from 0.0001 to 0.0007 per cent. Due to the presence of over 3 per cent carbon and over 2 per cent of silicon, very little MnO can be expected.

The presence of FeO in cast iron has been the subject of some speculation when oxides in cast iron are discussed. With one exception, the FeO in the gray iron is very low, the average of the 12 tests being 0.0050 per cent. This FeO may be present in two forms; (1) In pure form as dissolved FeO; (2) combined with silica to form a high melting point ferrous silicate. The dissolved FeO is controlled by the silicon present, as

$$2FeO\ (\%\ in\ Fe) + Si\ (\%\ in\ Fe) = 2Fe\ (liquid) + SiO_2\ (crystalline)$$

According to Chipman,[6] at equilibrium,

$$(per\ cent\ FeO)^2 \times (per\ cent\ Si) = 0.48 \times 10^{-4}\ (1600^\circ\ C.)$$

The average silicon, excepting the sample from foundry D. is 2.26%. According to the above equation,

$$(FeO)^2 = \frac{0.48 \times 10^{-4}}{2.26} = .212 \times 10^{-4}$$

$$FeO = 0.0046\%.$$

This value is in such good agreement with the experimentally determined value that there must be very little FeO combined wih the silica. This conclusion is substantiated by the observations made with the binocular microscope on the oxide residues. The extracted inclusions were very small and crystalline, appearing to be very nearly pure silica. Some appeared to have slight yellow coloration, and some were associated with graphite particles. In these cast irons, it appears that equilibrium was reached in the cupola and in the ladle.

The sampling study indicated that the oxides are evenly distributed in the chill cast iron bar. This is shown by the results listed in Table 2.

To the initiate, these results show exceptional reproducibility, indicating that the sampling and the method of determination are reliable. The only other data with which

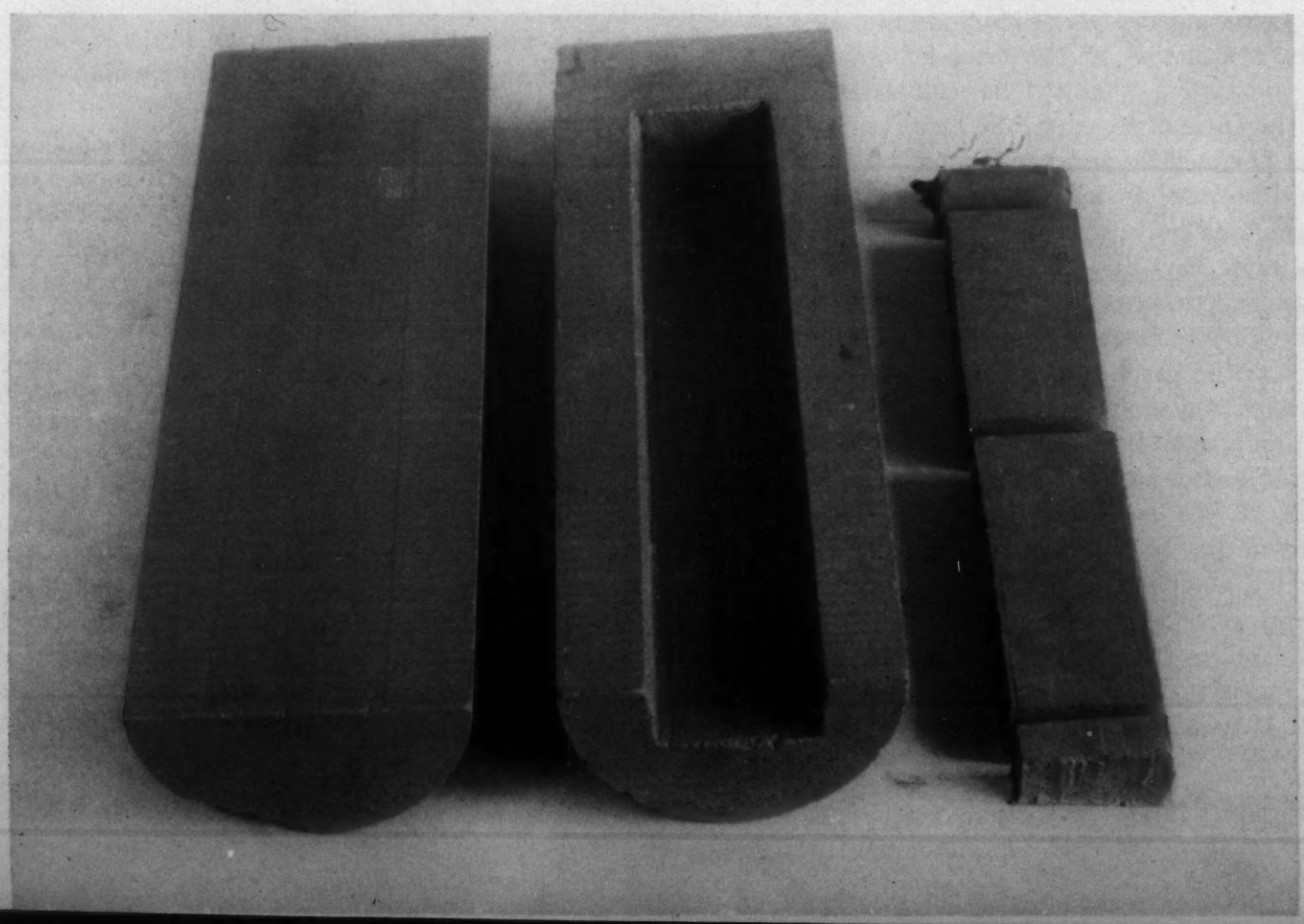


Fig. 1. Split Graphite Mold and Sampled Cast Iron Bar.

Fig. 2. Inclusions and Graphite Structure in Gray Cast Iron—Unetched. 500X.

Fig. 3. Inclusions and Graphite Structure in Gray Cast Iron—Unetched. 500X.

we can compare these results are those obtained by the vacuum fusion or hydrogen reduction methods. Comparing the calculated oxygen of the compounds determined,

Table 2. Distribution of Oxides in Test Bars

Foundry	Sample	SiO_2	MnO	FeO	Calc. O_2
	Top of bar	0.0051	0.0002	0.0038	0.0036
	Middle of bar	0.0063	0.0003	0.0027	0.0040
	Bottom of bar	0.0072	0.0003	0.0041	0.0048
	Top of bar	0.0076	0.0002	0.0062	0.0054
	Middle of bar	0.0055	0.0002	0.0054	0.0042
	Bottom of bar	0.0038	0.0001	0.0033	0.0028
	Top of bar	0.0045	0.0002	0.0053	0.0036
	Middle of bar	0.0044	0.0003	0.0103	0.0047
	Bottom of bar	0.0032	0.0001	0.0065	0.0031
	Top of bar	0.0064	0.0004	0.0056	0.0047
	Middle of bar	0.0039	0.0003	0.0075	0.0038
	Bottom of bar	0.0087	0.0003	0.0053	0.0058

we find that they check within a limit of ± 0.002 per cent O_2, which is the accepted value for the permissible variation in tests made by these other methods.

These four samples were chosen as they represent *different* foundry practices. Foundry D produced the iron in a cupola using 40 per cent Bessemer steel scrap with 60 per cent pig iron. This iron was used in heavy machinery castings. Foundry A used nothing but scrap gray iron castings, old heavy machinery parts. Sample No. 6 was produced in a Detroit electric rocking furnace, and represented the usual practice. Sample No. 7 was similarly produced, but was superheated and a special flux used. This flux was reputed to make the iron cleaner and stronger. Foundry C specializes in tractor parts, and represents normal cupola, gray iron production, using pig and 10 to 15 per cent steel scrap iron in the charge. In Table 1, three different runs are listed, samples C 1 and C 2 being lower in oxides than C 3. All runs have oxides of nearly the sample analysis, but not in the same amounts.

A study of the oxide analysis shows that the oxides in the test bars have rather definite compositions. Referring

Fig. 4. Inclusions and Graphite Structure in Gray Cast Iron—Unetched. 500X.

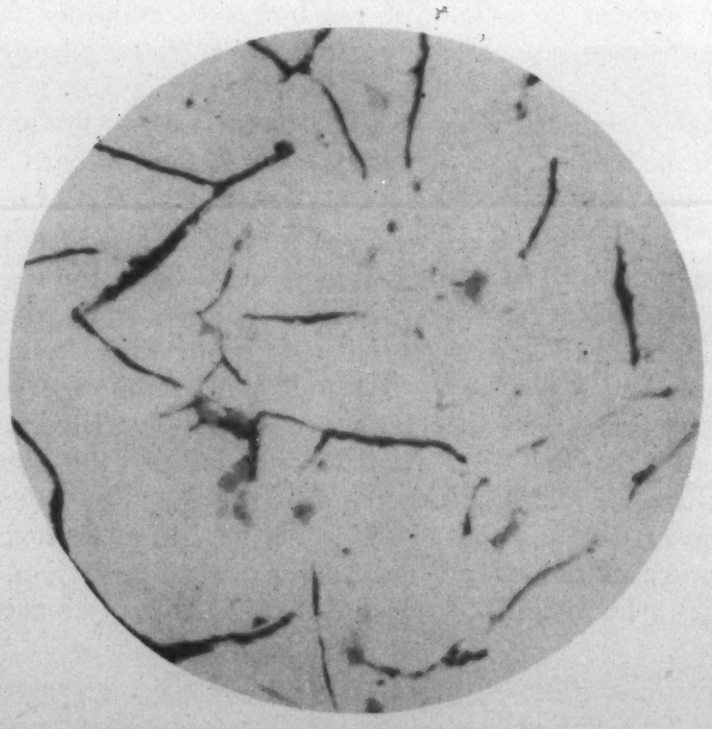


Fig. 5. Inclusions and Graphite Structure in Gray Cast Iron—Unetched. 500X.

Fig. 6. Inclusions and Graphite Structure in Gray Cast Iron—Unetched. 1000X.

to Table 3, the oxides in Foundry D iron are more siliceous than any found in the other irons, excepting of course those that were sand cast and contaminated. Sample A 6 has slightly more FeO in the residue and A 7 appreciably more FeO. The oxide residue from iron C 3 does not show such definite analysis in all parts of the bar.

Table 3. Composition of Extraction Residues

Foundry	Sample	SiO_2	MnO	FeO
D	Top of bar	56.0	2.2	41.8
	Middle of bar	67.8	3.2	29.0
	Bottom of bar	62.0	2.6	35.4
A 6	Top of bar	54.3	1.5	44.2
	Middle of bar	49.5	1.8	48.7
	Bottom of bar	52.8	1.4	45.8
A 7	Top of bar	45.0	2.0	53.0
	Middle of bar	29.3	2.0	68.7
	Bottom of bar	32.7	1.0	66.3
C 3	Top of bar	51.6	3.2	45.2
	Middle of bar	33.3	2.6	64.1
	Bottom of bar	60.8	2.1	37.1

Microscopic Examination of the Cast Irons

A number of samples of cast iron were examined under the microscope to study the type of inclusion present, its distribution, and its association with the graphite. All samples were cast under similar conditions, and the section examined was cut from similar location in each bar. The examinations were made at 100, 500, and 1000 diams.

The graphite, in all cases was present in long flakes, although there was a slight difference in thickness and lengths at times. No conclusions could be drawn as to whether the oxides had acted as nuclei for graphitization. Referring to photomicrographs, Figs. 2 and 3, it would appear that the inclusions and the graphite were not associated. Figs. 4 and 5, on the other hand, seem to indicate that the inclusions are often associated with the graphite. Fig. 6, taken at 1000 magnifications, would tend to prove that the presence of non-metallics did influence graphitization. It shows a field similar to that pictured in the upper part of Fig. 5.

The crystalline shapes of the non-metallics suggest that they have varied compositions. The triangular types in Fig. 2 were seen many times in the irons, and suggest that there may be some Al_2O_3 present. Others suggest the presence of titania and silica. No doubt some of the particles are sulphides, as manganese sulphide. Future studies of the oxide residues under the polarizing microscope will afford more definite information as to their identities.

Fig. 6 affords some definite proof that certain of the oxides or sulphide inclusions have melting points so low that they coalesce during the freezing of the iron. Even though they have started to assume definite crystalline forms, they are seen to be fused together.

Conclusions

Typical gray irons have been analyzed for oxides, and it has been observed that;

(1) Tests cast in dry sand molds are contaminated by the sand.

(2) Tests cast in cold graphite molds are satisfactory for analysis.

(3) A section cut anywhere from this test bar will give satisfactory and representative oxide analyses.

(4) The oxide residue is principally silica and ferrous oxide.

(5) The ferrous oxide percentage is controlled by the silicon-ferrous oxide equilibrium.

(6) The ferrous oxide is so close to the equilibrium value that most of the FeO is present as such in solution, and very little is present as silicate.

(7) The conclusion noted in (6) is supported by the examination of the residue under the microscope, and by the crystalline appearance of the oxides seen in the iron.

(8) The microscope gave no evidence to support the theory that graphitization was dependent upon the presence of non-metallic nuclei. Some inclusions appeared to be associated with the graphite. No nodular graphite was seen, and no irregularities were observed.

(9) The presence of so many crystalline shapes suggested that there were present different oxides. Petrographic studies would be helpful.

(10) In no case was a high oxygen content found. The total oxygen, calculated from the oxides found by analysis, ranged from 0.0027 to 0.0059 per cent.

Footnote

The authors invite any reader having a sample of abnormal cast iron, believed to be highly oxidized, to submit the same for oxide analysis and microscopic study. In order to clarify the situation regarding the relationship between oxides and graphite structure, it will be necessary to obtain such samples for study. The sender should also include all possible history of the sample in order that the study may be of value.

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Carbonized Nickel for Radio Tubes

by T. H. Briggs

Raytheon Production Corp.,
Newton, Mass.

Of vital importance to the entire radio industry is the blackened nickel from which are made the "plates" in the millions of receiving tubes produced each year. The plates should be black to prevent their running hot and developing "back emission," but the number of suitable coatings is definitely limited by requirements of stability, adhesion, pliability, uniformity, freedom from dissolved or adsorbed gases, absence of unstable compounds that evolve gases on heating in a vacuum, etc. This article describes, for the first time outside of the patent literature, the blackening of nickel by "carbonizing," now firmly established as the best black-coating process yet developed for this purpose. The very interesting analogy between this process and the better-known gas carburizing of steel is brought out by the author.—The Editors.

THE USE OF CARBONIZED NICKEL for radio tube anodes (plates) started about 1927 with the necessity of reducing back emission in the newly developed a.c. rectifier tubes. For the most efficient tube operation, the anode should collect all the electrons emitted by the heated cathode (filament), but the bombardment of electrons on the anode raises its temperature to such a point that, unless the heat is suitably dissipated, the anode itself becomes an emitter and the efficiency of the tube is reduced. Blackening the plates with a carbon coating to increase their radiating ability effectively solves this problem. Also, in addition to the effect of surface carbon in lowering the plate temperature, the back emission is further lowered by the tendency of the carbon to combine with any barium sublimed from the filament coating to the plate, and thus render it inactive as an electron emitter. Other uses for this material rapidly arose, first in the 210 and 250 tubes as a less expensive plate material than the sand-blasted molybdenum. The 245 and the 280 were the first large production tubes using carbonized nickel.

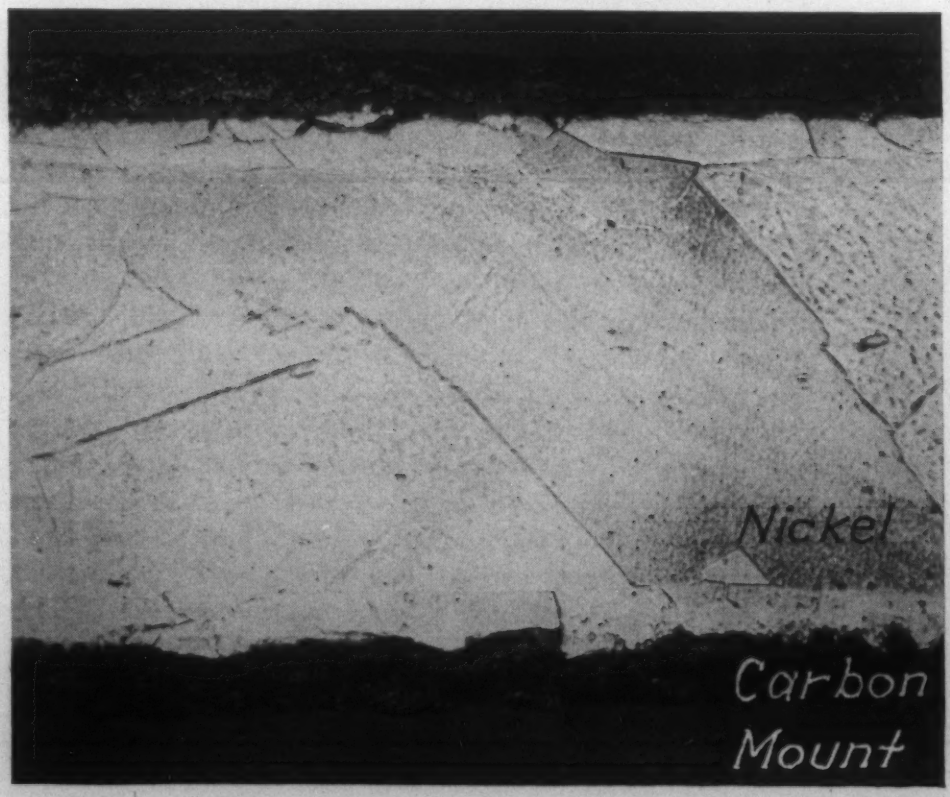
Properties of Carbonized Surfaces

"Carburizing" is a term well-known to the steel industry but is purposely not used in referring to the blackening of the surface of nickel, for entirely different reactions are involved. In carburizing, a hardening of the surface of steel is obtained by increasing the carbon content, leaving a shiny metallic surface. This may result in carbon penetration for as much as an inch and a quarter. Carbonizing of nickel, however, does not materially harden the metal, and the surface is covered with a sooty carbon layer physically bonded to the grain structure of the nickel, as is shown in Fig. 1. Chemical analyses and metallographic examination fail to show a significant increase in the carbon content in the nickel itself.

According to Barnes[1] the total radiation in watts per sq. cm. for sooted or carbonized material is 4.8, and for bright nickel it is only 0.78 at 727 deg. C. (1000 deg. K.) Similarly the total emissivity at 727 deg. C. is approximately 0.85 for the carbonized nickel and 0.16 for bright nickel. Barnes's early work was done with .010″ wire. Recently this has been roughly checked using present day carbonized ribbon, and the results have been found in good agreement.

A simple and practical method of determining the comparative effectiveness of carbonized plates with respect to woven mesh, sand-blasted or bright nickel plates, is to

Fig. 1.—A Cross Section of Carbonized Nickel as Seen Under the Microscope, Etched; Magnification 500 X.



measure the plate input watts possible for development of a given grid emission current. This has been done for the type 47 tube and shows that to give a fixed grid emission value the plate and screen grid currents multiplied by the plate voltage resulted in about 20 watts plate input for carbonized material, whereas a dull finished nickel could stand less than 14 watts, and bright nickel less than 9 watts.

By examining cross sections of strips of carbonized nickel a clear picture is obtained of the mechanism of the carbonizing reactions. Again referring to Fig. 1, large nickel crystals may be seen extending practically the whole thickness of the ribbon sample (0.005 in.). At the surface, small grains (0.001 in. deep) have been formed in the processing of the ribbon for carbonizing. Along these grain boundaries fine strings of carbon have been deposited, which materially assist in the adherence of the whole surface layer. The carbon layer in this particular case is about 0.0005 in. thick; normally it may be expected to be between 0.0002 and 0.0003 in. thick.

The Carbonizing Process

The process of carbonizing nickel is accomplished at present through formation of a green oxide by heating the nickel parts or ribbon in air to about 925 deg. C., then almost immediately placing it in another furnace at the same temperature in a hydrocarbon gas atmosphere. The nickel oxide may act as a catalyst and crack the gas into its carbon and hydrogen components. The hydrogen reduces the oxide, and the water formed and the excess hydrogen are carried off with the surplus hydrocarbon gases. The carbon at once deposits on the active nickel surface. The oxidation and reduction of the nickel surface itself tends to open up the grain boundaries and generally roughen the nickel surface. Other roughening is frequently used, such as by mechanical,[17, 36] or chemical means, or an earlier carbonization and oxidation.[14] Above all a clean, active, nickel surface is necessary, uncontaminated by old, deep-grown oxides, finger marks, oil, dust, or mechanical scars. The speed of carbon deposit and its depth or darkness of color depend largely upon the effectiveness of the preparation of the original nickel strip. Once the carbon begins to deposit on the strip it does so rapidly and after that any increased time in the furnace will have little additional effect.

There is some question as to the exact composition of the carbon layer. The black, sooty type is generally supposed to be amorphous carbon, although some claim it to be a hydrocarbon with a large number of carbon atoms to one of hydrogen. The gray finish, having a lighter appearance, is thought to be graphitic in nature, inasmuch as it is obtained by a higher furnace temperature, is harder, and more dense.

The first carbonizing was done by the so-called "batch" process, in which completely fabricated radio tube parts were packed in boats, placed in a sealed furnace muffle and exposed to a hydrocarbon gas. The most generally used gas is a commercially available mixture of propane and butane. However, a long series of gases and mixtures has been tried with more or less success. Some of these have been methane, acetylene, natural gas, casing-head gasoline, as well as hydrogen bubbled through petroleum ether. The furnace was heated to about 925 deg. C. and the parts were required to stay in the muffle anywhere from 15 to 45 min. With that process there was great variation in the results so that many plates had to be decarbonized in hydrogen furnaces and retreated. The next important development was the oxidation of the nickel surface just prior to carbonizing, which gave more uniform results and a deeper carbon penetration.

Continuous Carbonizing

"Continuous" carbonizing followed as a logical step in obtaining a process with fewer undesirable variables and permitting more automatic operation. The nickel ribbon was fed through muffles open to the air to form the nickel oxide, then at once into the carbonizing muffle where the hydrocarbon gas was "cracked" and reacted with the nickel oxide. As the hydrogen and carbon molecules condensed in the cooler portion of the muffle they recombined to form complex polymers of an oily, tarry nature. These deposited in the absorptive carbon layer on the ribbon and unless properly treated were—and are—very harmful to cathode emission. This difficulty has generally been avoided by preventing the polymerization from taking place in the presence of the carbonized nickel. The carbonized ribbon is passed through a diaphragm in the outgoing end of the muffle into air or a neutral gas atmosphere while still hot, before the cracked gases have an opportunity to polymerize. Also the gases are burned off through an escape pipe while still hot. In cases where polymers were present they could later be dissolved by trichlorethylene or triethanolamine but only after long soaking. Vacuum baking most effectively eliminates this impurity when it is present.

But even with automatic temperature, speed, gas flow, and other controls the variations in product were excessive, and indicated the need for improvements in the nickel surface itself. Acid etching to roughen the ribbon was not a sufficient improvement, and in addition, was irregular, and left a residue of etchant difficult to remove. Oxidation and reduction, either by frequently repeated or by long single cycles, was feasible but often resulted in poor radio tube life. This might be explained by deeply penetrated oxides finally coming to the surface and depressing the cathode emission. A sand-blasted surface has proved most desirable so far, but extreme care must be taken to keep the sand sharp and clean, and to reanneal the disintegrated surface particles to produce a grain structure similar to that shown in Fig. 1. Finally, the author conceived and carried out the idea of placing the ribbon under tension as it passes through the muffles. This effectively "works" the grains and increases carbonizing speeds, or the depth of carbon penetration. The explanation for this may lie in the fact that the oxidized surface is greatly increased, and also that a surface under strain is more active chemically than if the strain is not present.

As more new electronic tube types were introduced and voltage ratings increased, the use of carbonized nickel plates rapidly increased. The result, as shown in Fig. 2, was the building of large furnaces. At the left is one of the first continuous carbonizing furnaces with a maximum linear capacity for both muffles of only 250 ft. per hr. At the right is one of the most recently built carbonizing trains which now has a linear capacity as high as 1800 ft. per hr. The nickel ribbon, varying in widths from about ½ in. to as great as 6 in., is passed through the small oxidizing furnace (in the center background), then through the long carbonizing furnace, and is coiled on wind-up reels in the right foreground. After carbonizing, the wider ribbons are generally slit to the required widths. The muffles are

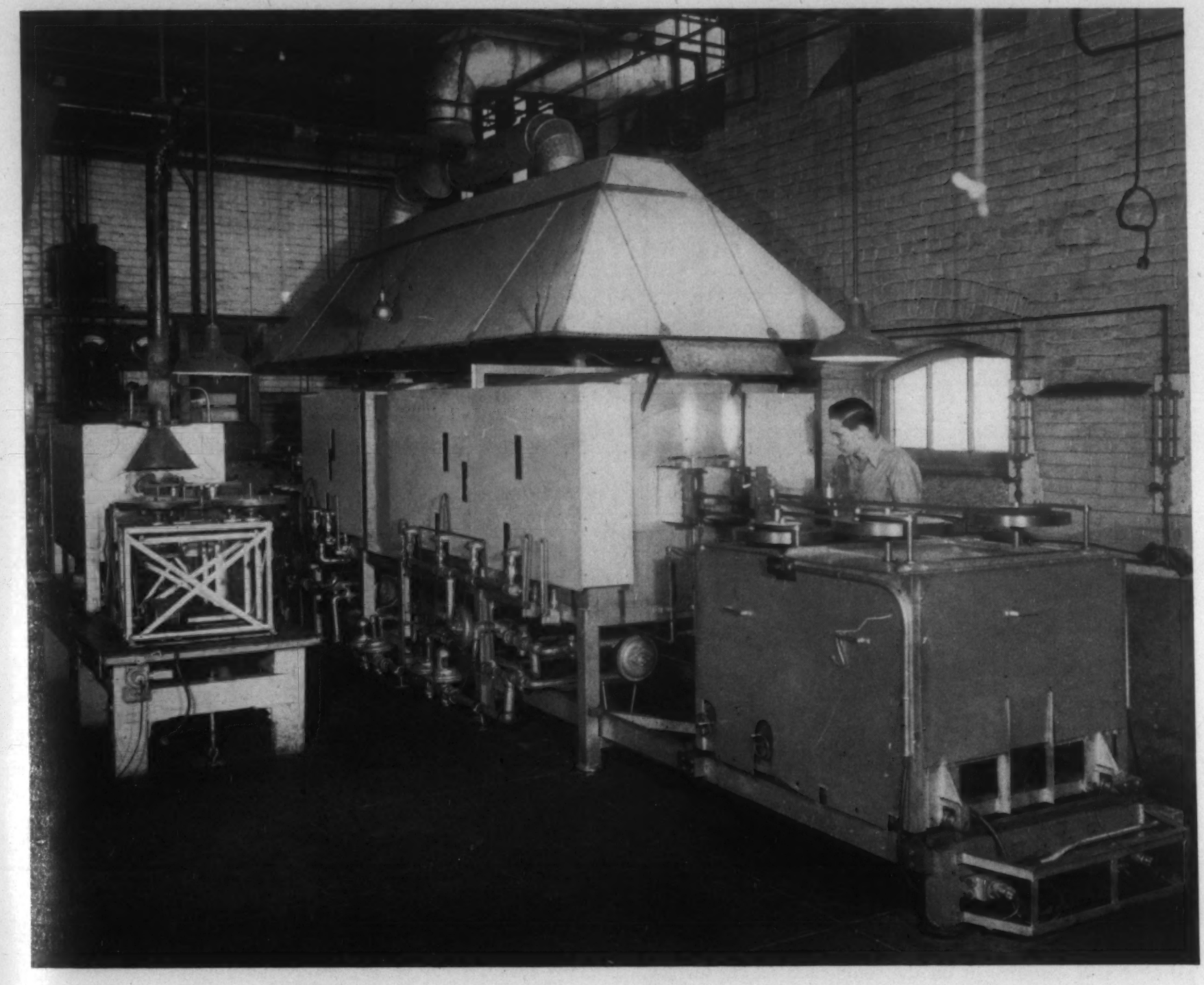


Fig. 2.—Two Types of Continuous Carbonizing Furnaces. At left, early small furnace with maximum linear capacity of 250 ft. per hr.; at right, modern large furnace capable of handling 1800 ft. per hr.

rectangular in cross section, measuring 2½ in. x 9¾ in., and for carbonizing are 9 ft. long. The furnaces require accurate and uniform temperature control over the entire muffle length to avoid building up uneven carbon deposits on their walls. The fuel controls are shown under the furnaces, while the temperature recorders are behind the train. The flow-meters for the hydrocarbon gas are on the wall back of the operator, while the burn-off plume of excess gas is seen at the end of the muffle.

The wind-up arrangement consists of eight variable speed drives, connected two to each reel. The ribbon is pulled through the furnaces by a motor-driven wind-up reel. This would give a constantly increasing linear speed with increasing roll diameter except that a variable speed drive controlled by a lever arm touching the diameter of the roll reduces the angular speed with increasing periphery. This rather complicated system is preferred to using draw rolls that press against the ribbon itself, and a friction driven wind-up reel, since lateral ribbon bow and surface scratches are reduced to a minimum. The second variable speed drive is in series with the first and permits variations in linear ribbon speed as necessitated by the ability of the nickel to accept carbonizing. This may vary over quite wide ranges, depending upon the surface conditioning applied before the oxidizing furnace.

Other Carbonizing Methods

Because so few technical articles have been written on this subject, descriptions of processes used or suggested are generally available only in the patent literature. Examination of the patents listed at the end of this article shows that many carbonizing furnaces and methods have been tried. Some have had vertical muffles, others have combined the basic oxidizing and carbonizing processes in a variety of ways. One method[12] involves heating the nickel by its own resistance, employing this heat to vaporize and then crack the desired hydrocarbon. Another suggested method, which now seems feasible, is to heat the ribbon by high frequency induction and utilize its heat to crack the gas. In all methods, however, the optimum preheating and carbonizing temperatures appear to lie between 870 and 1050 deg. C., although temperatures as low as 600 deg. C. and as high as 1100 deg. C. have been successfully used.

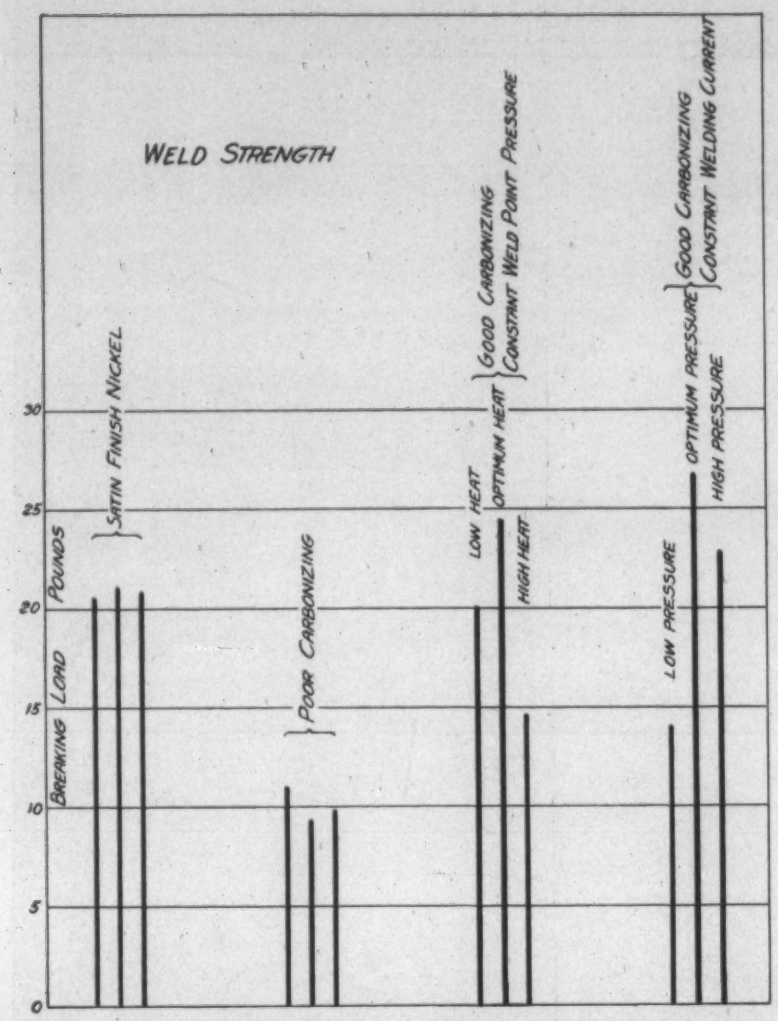


Fig. 3.—Strengths of Single-Point Welds of Carbonized Nickel as Affected by Carbon Coating, Welding Current, and Welding Pressure.

Further, the pretreatment of the nickel ribbon is highly important for all methods.

A most successful and large scale means of carbonizing by a method other than gas cracking was devised by C. Eddison[13] whose patent application was filed in 1933. This involved making a paste of carbon black, lard oil, and palmitic acid, painting it on the roughened nickel surface, then breaking these hydrocarbon compounds down into their components at a low temperature of about 300 to 675 deg. C. It has been possible by this paste method to carbonize successfully not only nickel but also nickel-plated steel and pure iron. The nickel plating is only 0.0002 in. thick.

The application of difficult coatings by cataphoresis finds a wide range of use in the vacuum tube industry. Several patents have been taken out covering such a method for obtaining black coatings on anodes—notably by the Philips Co.[19, 40] of Holland. Little can be said yet concerning this process, but it would seem to have wide possibilities. Essentially it consists of obtaining the proper alkaline colloidal solution of finely divided carbon particles. With the ribbon as one electrode and between 40 and 200 volts d.c. a satisfactorily thick coating may be deposited in a few seconds.

Grid wire has been carbonized at relatively high speeds with a firmly adhering carbon deposit, which is a very satisfactory substitute for anti-grid-emission coatings generally sprayed on grids after winding.

Other Types of Black Anodes

So far only nickel has been mentioned as a base for carbonizing. In the case of grid wires some other materials have been treated, such as molybdenum, molybdenum-nickel-iron alloy, and manganese-nickel. For ribbons, it has been very difficult, up to the present, to obtain uniformly good results with pure iron or even nickel plated iron with this gas method; carburizing results, the iron becomes brittle, and the heat radiating qualities are poor.

In attempts to use less expensive anodes, oxides of nickel or other dark oxides have been deposited on iron or nickel plates. Umbreit[2] reports that these have generally failed due to evolution of gases during life. However, one successful process early recorded in the field was that of Kelley[3] at Western Electric, whose patent application was filed in 1919. Some of the oxides tried have been those of tantalum, molybdenum, chromium, and tungsten.[22] Also, in Germany, chlorides of iron have been tried.[24, 25]

For large tubes, generally of the transmitting types, graphite anodes[11, 16, 18, 39] have been used extensively. These are made by accurate machining of graphite blocks to the sizes and shapes specified. Before being ready for use, however, they must be treated to remove any possible traces of amorphous carbon or its compounds. Air firing by furnace or induction heating is used to bring the plate to a high temperature, which is maintained while a film of burning gases remains. Then the graphite is quickly dropped into water or other liquid to dislodge loosely adherent particles. By another process[16] fine graphite particles are sprayed onto the graphite anode and additional air firing is given to produce a hard smooth finish.

Testing of Carbonized Nickel

There are several tests that experience has shown it is wise to give carbonized material from time to time as a check on quality. The foremost of these determines how well the carbon coating will adhere. This may be done by exposing a sample to a hydrogen atmosphere in a furnace at 1000 deg. C. for 1-2 min.; or exposing it for 30 min. in a vacuum furnace at 1100-1300 deg. C. Good material will show little or no change in color under this test, w hile poor material will be partially or entirely decarbonized.

Also important is the welding test. Due to the high-resistance carbon layer on the nickel, electric spot welding of two samples of carbonized nickel is much more difficult than with bright nickel. The carbon layer may be too thick for satisfactory welding, or it may be spotty so that weak pin-point welds result. Infrequently, the nickel may be "diseased" by a high-resistance oxide film along the grain boundaries, resulting in high welding resistance. Welds may be tested in three ways—bend, shear, and straight tensile pull—each representative of some service condition. Generally, a given number of welds are made with uniform welding conditions and the various samples compared. The graphs of Fig. 3 compare the straight tensile pull strength of a single point weld on (a) uncarbonized nickel, (b) poorly-carbonized nickel and (c) well-carbonized nickel with low, correct, and high welding currents, and low correct and high welding point pressures.

A method has been proposed[15, 38] for removing excess loose particles of carbon from graphite anodes. This consists of heating the material in air by radio frequency bombardment or in a hydrogen furnace, then rapidly immersing in water. The theory advanced has been that the steam instantaneously generated at the hot metal or inner carbon surface blows out and removes many loose carbon particles. This method is satisfactory for graphite or carbonized nickel fabricated parts where submersion is rapid, but for

carbonized nickel ribbon an increase in width may result, owing to the strain of the expanded, heated metal which prevents the quenched metal immediately adjacent to it from contracting. As much as 0.020-in. increase in width of a 1-in. ribbon is possible. By quenching heavily carbonized plates where electrical spot welding is difficult because of excess loose carbon particles, it is possible to obtain a surface that provides satisfactory welding.

The gas content of carbonized material is frequently determined, since this is an important factor in the actual manufacture of radio tubes. Either a complicated qualitative analysis may be made, or a simple quantitative check. This latter consists only in measuring the volume of gas liberated per unit weight or area of a sample when heated by radio frequency bombardment to a given temperature (about 900 deg. C.) For example bright nickel ribbon may have 50 units of gas; after carbonizing by one method the gas content may increase to about 150 units, while carbonizing in another way may give as high as 550 units. Such high gas contents make degassification necessary before assembly on to the radio tube mount. This degassification may be accomplished by hydrogen firing for a brief interval, but only surface gases are removed and some light hydrogen replaces heavier and more tenacious gas. Vacuum baking for half an hour at elevated temperatures is probably the most effective treatment. In such cases, the gas content may be halved.

References

The author in compiling and analyzing the patents listed below has made no attempt to evaluate the claims thereof. His interest has resided solely in the descriptive subject matter which each patent contains. Also, he has made no attempt to select the first patent in each instance that contains a description of the subject matter to which he refers. It should also be understood that the patent bibliography is not necessarily complete.

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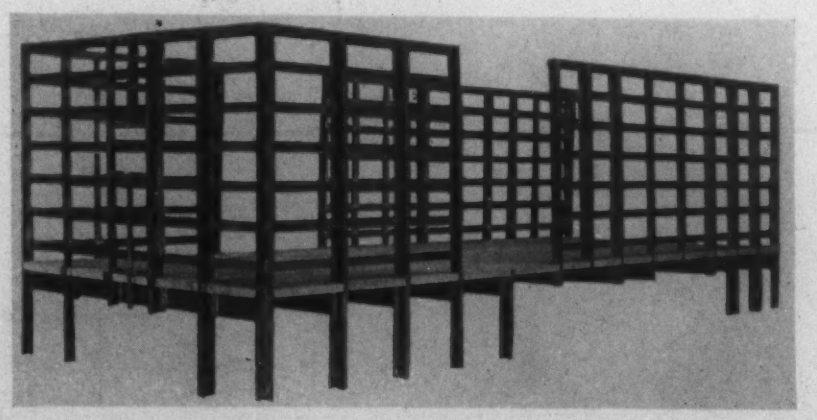
More About Low Alloy, High Strength Steels

Large Truck Body Made of "AWDyn-El" Steel

Because of the receipt, too late, of photographs of installations of the new low alloy high strength steel—AWDyn-El—of the Alan Wood Steel Co., Conshohocken, Pa., for incorporation in the survey of these steels, published in the October issue of METALS AND ALLOYS, we present here some data of this nature.

A large truckbody—225 in. long by 82 in. wide and 52 in. high—has been made of this new steel. It was built by Barry & Bailey Co., Philadelphia. One illustration shows the body and the other sub-structure. The weight of the body, made of Dyn-El



is 3265 lbs. in contrast to 5300 lbs. if made of ordinary carbon steel sections—a saving of 2035 lbs. The various posts, angles, rails, cross-bars and so on are made of steel from 10 to 16 gage bent to form.

Ductiloy

Under "Current News," pages 685 to 687, will be found more data about the new steel—"Ductiloy"—of the Great Lakes Steel Corp.—EDITOR.

Courtesy: Ford Motor Co. of Canada, Ltd.

Pouring Cu-Si Iron from a 4-Ton 'Lectromelt Furnace

Some Useful Probability Tables

by H. V. Johnson

American Cast Iron Pipe Co., Birmingham, Ala.

This article is of decided practical interest to foundrymen. It is not practicable to test all of a company's products thoroughly and hence only a percentage of a large number of castings, for example, are used. The author offers two tables of probabilities which are believed, from actual experience in the company's foundry with which the author is connected, to throw some light on the true value of representative sample tests.—The Editors.

EACH YEAR MORE EXACTING specifications, keener competition, and the effort to manufacture a better product sees the completion of an ever increasing number of laboratories and testing departments. Rigorous inspection, routine in most industries, also adds to the wealth of data supplied to departmental heads.

The methods of testing have been more or less satisfactorily solved, but analysis of the resulting data is still a major problem. Data without significance, or misinterpreted, are not only wasteful but harmful.

Since it is not practicable with most industries to test all of their products as thoroughly as they would like, only a certain percentage or representative samples are so used. Especially is this necessary where the tests result in destruction of the specimen.

The author offers two tables that may shed some light on the true value of these representative sample tests. The tables given, or similar tables more applicable to a particular product, are used to evaluate the significance of a given series of tests with respect to the entire output.

For example, if it is known that the long time average number of defectives is 10 per cent, and in the course of one day's testing of a sample of 25 specimens, there occur 6 defectives, we find from Table I that the probability

TABLE I.—PROBABILITY OF OCCURRENCE OF DEFECTIVES

THE LOT IS CONSIDERED INFINITE

$$P_m = \frac{/n}{/n - m\ /m} \cdot (1 - p')^{n-m} \cdot (p')^m$$

P = Probability
m = Number of defectives in sample
n = Sample size
p' = Fraction defective in lot

10 PER CENT OF ALL SPECIMENS DEFECTIVE

In a group of 10 specimens tested, the probability that exactly a specific number will be defective is:

0—0.34868	or	1	in	3
1—0.38742	or	1	in	3
2—0.19371	or	1	in	5
3—0.057395	or	1	in	17
4—0.011160	or	1	in	90
5—0.0014880	or	1	in	670

For a group of 25 specimens tested:

0—0.07178	or	1	in	14
1—0.19939	or	1	in	5
2—0.26586	or	1	in	4
3—0.22647	or	1	in	4
4—0.13871	or	1	in	7
5—0.06459	or	1	in	16
6—0.02392	or	1	in	42

For a group of 50 specimens tested:

0—0.005152	or	1	in	200
1—0.02862	or	1	in	35
2—0.07792	or	1	in	13
3—0.13853	or	1	in	7
4—0.18086	or	1	in	6
5—0.18487	or	1	in	5
6—0.15393	or	1	in	6
7—0.10763	or	1	in	9
8—0.06428	or	1	in	16
9—0.033329	or	1	in	30
10—0.015184	or	1	in	66
11—0.006135	or	1	in	163
12—0.002215	or	1	in	452

For a group of 100 specimens tested:

0—0.0000265	or	1	in	38,000
1—0.000295	or	1	in	3,400
2—0.00162	or	1	in	600
3—0.00589	or	1	in	170
4—0.01587	or	1	in	63
5—0.03385	or	1	in	30
6—0.05955	or	1	in	17
7—0.09480	or	1	in	11
8—0.10960	or	1	in	9
9—0.13035	or	1	in	8
10—0.13180	or	1	in	8
11—0.11982	or	1	in	8
12—0.098788	or	1	in	11
13—0.074302	or	1	in	13
14—0.051304	or	1	in	19
15—0.041145	or	1	in	24
16—0.019292	or	1	in	52
17—0.010592	or	1	in	94
18—0.005427	or	1	in	184
19—0.002602	or	1	in	384
20—0.001171	or	1	in	854
21—0.000496	or	1	in	2,015
22—0.000198	or	1	in	5,050
23—0.000075	or	1	in	13,350
24—0.000027	or	1	in	37,000

5 PER CENT OF ALL SPECIMENS DEFECTIVE

For a group of 10 specimens tested:

0—0.59874	or	1	in	2
1—0.31513	or	1	in	3
2—0.074635	or	1	in	13
3—0.010475	or	1	in	96
4—0.0009648	or	1	in	1,040
5—0.0000609	or	1	in	16,400

For a group of 25 specimens tested:

0—0.27739	or	1	in	4
1—0.36499	or	1	in	3
2—0.23052	or	1	in	4
3—0.09301	or	1	in	11
4—0.026926	or	1	in	38
5—0.005305	or	1	in	190

For a group of 50 specimens tested:

0—0.076945	or	1	in	14
1—0.20202	or	1	in	5
2—0.26110	or	1	in	4
3—0.21987	or	1	in	5
4—0.13598	or	1	in	7
5—0.065841	or	1	in	15
6—0.02599	or	1	in	38

For a group of 100 specimens tested:

0—0.0059205	or	1	in	169
1—0.031160	or	1	in	32
2—0.081182	or	1	in	12
3—0.13958	or	1	in	7
4—0.17814	or	1	in	6
5—0.18002	or	1	in	6
6—0.15002	or	1	in	7
7—0.10602	or	1	in	9
8—0.06487	or	1	in	15
9—0.034901	or	1	in	29
10—0.016716	or	1	in	60
11—0.0071982	or	1	in	139
12—0.0028098	or	1	in	356

TABLE II.—PROBABILITY OF OCCURRENCE OF DEFECTIVES

THE LOT IS CONSIDERED FINITE

$$P_m = \frac{/N-n\ /n}{/N} \cdot \frac{/N-M}{/N-M-(n-m)\ /n-m} \cdot \frac{/M}{/M-m\ /m}$$

N = lot size
n = sample size
M = number of defectives in lot
m = number of defectives in sample

N = 100 M = 10 n = 25

m =					
0	0.047887.....	or	1	in	21
1	0.18139.....	or	1	in	6
2	0.29239.....	or	1	in	3
3	0.26372.....	or	1	in	4
4	0.14715.....	or	1	in	7
5	0.052974.....	or	1	in	19
6	0.012435.....	or	1	in	80
7	0.0018751.....	or	1	in	534
8	0.00017339.....	or	1	in	5,750
9	0.0000088516.....	or	1	in	113,000
10	0.00000018883.....	or	1	in	5,300,000

N = 100 M = 10 n = 10

m =					
0	0.33048.....	or	1	in	3
1	0.40800.....	or	1	in	2
2	0.20151.....	or	1	in	5
3	0.051794.....	or	1	in	19
4	0.0075532.....	or	1	in	132
5	0.00063980.....	or	1	in	1,560
6	0.000030998.....	or	1	in	32,250
7	0.00000081440.....	or	1	in	1,228,000
8	0.000000010411.....	or	1	in	96,000,000
9	0.000000000051992...	or	1	in	19,250,000,000
10	0.000000000000057769	or	1	in	17,320,000,000,000

N = 100 M = 10 n = 5

m =					
0	0.58375.....	or	1	in	2
1	0.33939.....	or	1	in	3
2	0.070219.....	or	1	in	14
3	0.0063689.....	or	1	in	157
4	0.000025093.....	or	1	in	39,850
5	0.0000033394.....	or	1	in	295,000

N = 50 M = 5 n = 25

m =					
0	0.025076.....	or	1	in	40
1	0.14926.....	or	1	in	7
2	0.32566.....	or	1	in	3
3	0.32566.....	or	1	in	3
4	0.14926.....	or	1	in	7
5	0.025076.....	or	1	in	40

N = 50 M = 5 n = 10

m =					
0	0.31056.....	or	1	in	3
1	0.43134.....	or	1	in	2
2	0.20984.....	or	1	in	5
3	0.044177.....	or	1	in	23
4	0.0039646.....	or	1	in	252
5	0.00011893.....	or	1	in	8,420

N = 50 M = 5 n = 5

m =					
0	0.57664.....	or	1	in	2
1	0.35161.....	or	1	in	3
2	0.066974.....	or	1	in	15
3	0.0046726.....	or	1	in	214
4	0.00010620.....	or	1	in	9,420
5	0.00000047197.....	or	1	in	2,120,000

N = 20 M = 2 n = 10

m =					
0	0.23684.....	or	1	in	4
1	0.52632.....	or	1	in	2
2	0.23684.....	or	1	in	4

N = 20 M = 2 n = 5

m =					
0	0.55263.....	or	1	in	2
1	0.39473.....	or	1	in	3
2	0.052632.....	or	1	in	19

N = 100 M = 5 n = 25

m =					
0	0.22925.....	or	1	in	4
1	0.40360.....	or	1	in	2
2	0.26907.....	or	1	in	4
3	0.084775.....	or	1	in	12
4	0.012602.....	or	1	in	79
5	0.00070569.....	or	1	in	1,420

N = 100 M = 5 n = 10

m =					
0	0.58375.....	or	1	in	2
1	0.33939.....	or	1	in	3
2	0.070219.....	or	1	in	14
3	0.0063836.....	or	1	in	157
4	0.00025104.....	or	1	in	3,990
5	0.0000033471.....	or	1	in	299,000

N = 100 M = 5 n = 5

m =					
0	0.76959.....	or	1	in	1
1	0.21143.....	or	1	in	5
2	0.018385.....	or	1	in	54
3	0.00059306.....	or	1	in	1,685
4	0.0000063092.....	or	1	in	158,500
5	0.000000013282.....	or	1	in	75,300,000

N = 60 M = 3 n = 25

m =					
0	0.19126.....	or	1	in	5
1	0.34528.....	or	1	in	3
2	0.30684.....	or	1	in	3
3	0.067212.....	or	1	in	15

N = 60 M = 3 n = 10

m =					
0	0.57276.....	or	1	in	2
1	0.35798.....	or	1	in	3
2	0.065751.....	or	1	in	15
3	0.0035068.....	or	1	in	285

N = 60 M = 3 n = 5

m =					
0	0.76666.....	or	1	in	1
1	0.21698.....	or	1	in	5
2	0.016073.....	or	1	in	62
3	0.00029223.....	or	1	in	3,435

N = 20 M = 1 n = 10

m =					
0	0.50000.....	or	1	in	2
1	0.50000.....	or	1	in	2

N = 20 M = 1 n = 5

m =					
0	0.75000.....	or	1	in	1
1	0.25000.....	or	1	in	4

of such an occurrence is 1 in 42. The probability is so small that we must immediately suspect a higher percentage of defectives for that particular day. If improbable numbers of defectives occur too consistently, then we must revise our previous conceptions of the long time average percentage of defectives.

Table I was calculated with the lot considered infinite, and the probability of the occurrence of exactly a specific number of defectives in a group was worked out for groups of various sizes. In this table one can apply previously conceived knowledge of the industry's long time percentage of defectives by merely looking under that percentage (here worked out for only 10 per cent and 5 per cent) at the group which corresponds with the size of that tested, and upon finding the number in the left column which is identical with the number of defectives he found, can, reading to the right, determine the probability of the occurrence, and gain some idea of how uniform his production is from day to day.

In Table II the lot was considered finite, with a definite lot size, sample size and number of defectives in the lot. Probabilities were calculated for the occurrence of exactly a certain number of the defectives in the lot being found in the sample. Here the same principle is applicable as before. The long time average presupposes a definite number of defectives in a certain size lot, for example, a lot size of 100 with 10 per cent defective would have 10 defectives in the lot. A sample to be tested is taken of a number of specimens, say 10. Simple arithmetic shows that the number of defectives should be 10 per cent of the sample as well as of the lot, or 1 defective, and we find that this is the most probable number from Table II. However if all 10 of the defectives in the lot of 100 should show up in a sample of only 10 we find the probability is only 1 in 17,320,000,000,000 or next to impossible with that percentage of defectives. Should a number of very low probability occur, it might be well to assume for that particular day a higher percentage of defectives.

Probabilities of the occurrence of several numbers, for example of 0, 1, 2, or 3 in a certain sample and lot are determined simply by adding the probabilities of the occurrence of each, in either table.

COMPOSITION AND PROPERTIES OF

Cupaloy in the "Time Capsule"

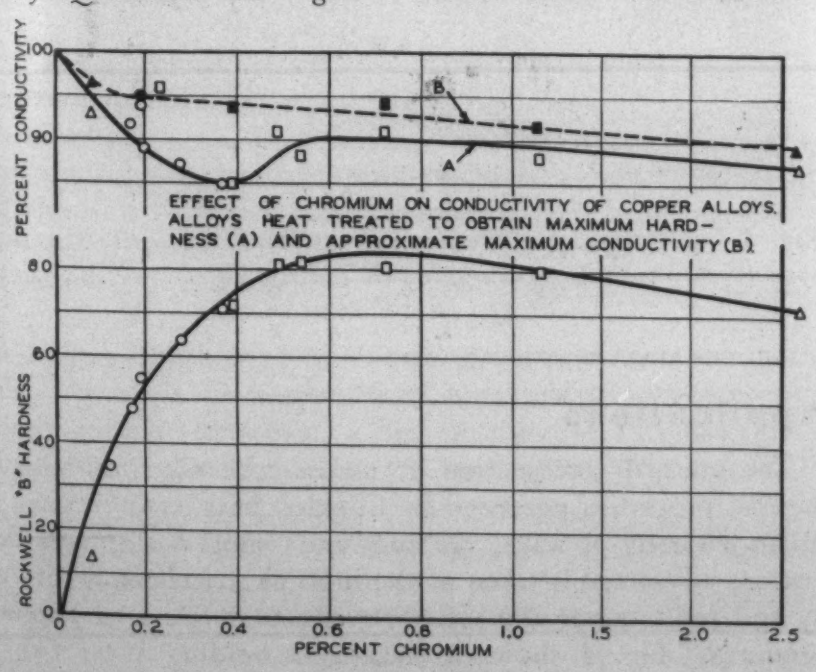
by P. H. Brace

Consulting Metallurgist, Research Laboratories,
Westinghouse Electric & Mfg. Co.,
East Pittsburgh, Pa.

Here in the New York area, and also in general, the announcement that the "Time Capsule," which is planned to remain buried some 5,000 years at the New York Worlds Fair site, was made of "Cupaloy" created no little interest and some curiosity. Because of this and also because it was of interest to know why silver was an alloying ingredient and what some of the other characteristics of the alloy are, we asked Dr. P. H. Brace, one of our editorial advisory board, to write a brief technical article, which we are glad to present. We believe this is the first authentic information regarding this alloy presented as an article.—The Editors.

IN THE "TIME CAPSULE," which is buried at the site of the Westinghouse Building at the New York World's Fair, a new alloy known as Cupaloy has been used. This is a copper alloy containing approximately one-half of one per cent of chromium and one-tenth of one per cent of silver. In other words the outstanding properties of Cupaloy have been obtained by adding to copper small amounts of other metals whose total is less than that of the alleged impurities in the traditional "99-44/100% pure Ivory Soap."

Fig. 1. Effect of Chromium of Hardness of Copper Alloys Quenched and Aged to Obtain Maximum Hardness.

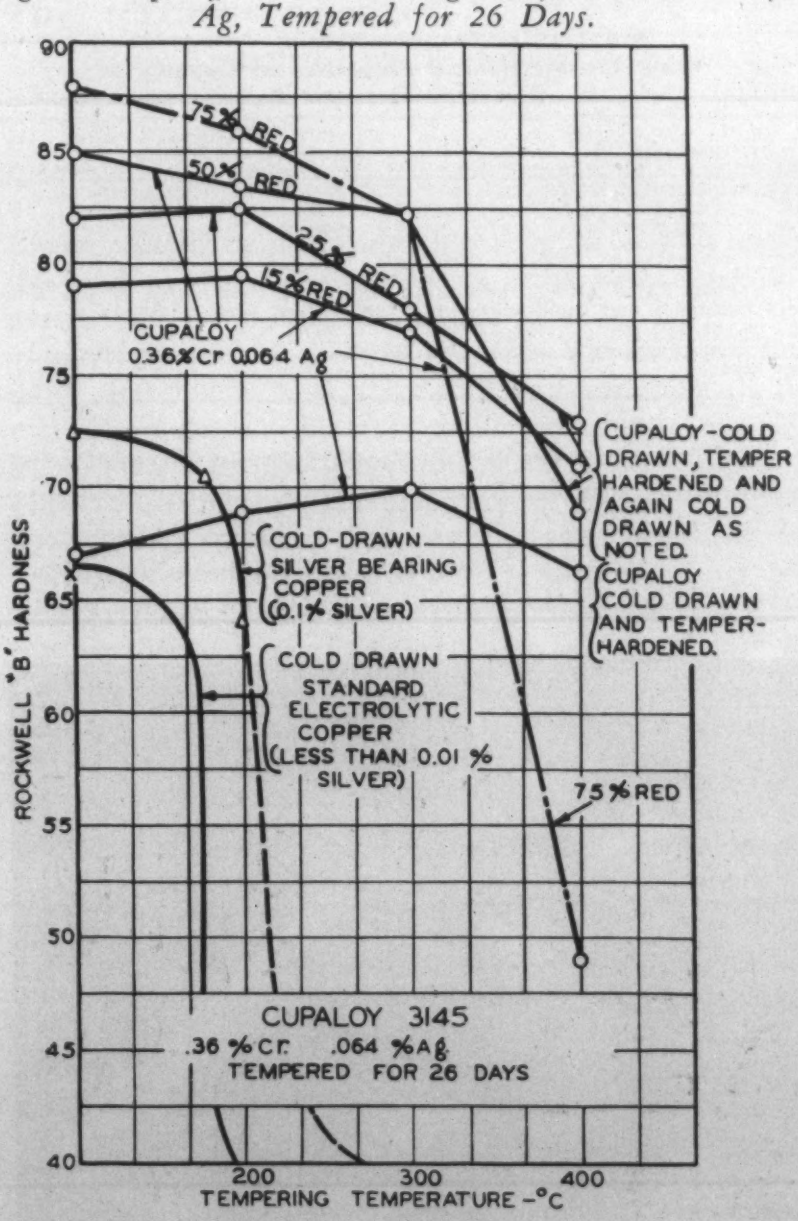


However the mere addition of these elements is not sufficient to produce unusual properties. Heat treatments supplemented in some cases by mechanical processing are necessary to make the alloying elements effective.

Heat Treatment for Hardening

In the untreated state, Cupaloy may show relatively low

Fig. 2. Cupaloy 3145 Containing 0.36% Cr and 0.064% Ag, Tempered for 26 Days.



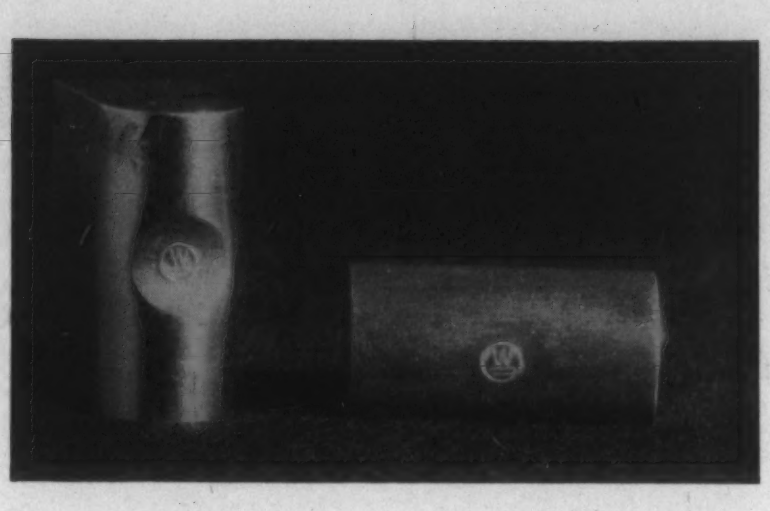


Fig. 3. A Graphic Demonstration of the High Strength of Properly Treated Cupaloy.

electrical conductivity and mechanical properties not far increased five-fold or more and the electrical conductivity raised to approximately 85 to 90 per cent of that of pure copper. Moreover, it is found that Cupaloy may be heated to relatively high temperatures for long periods without different from those of ordinary soft copper. However, by heating it to approximately 1000 deg. C. (1832 deg. F.), quenching in water and then "temper hardening" by heating at 450 deg. C. for 16 to 24 hrs. the elastic strength is serious loss of strength or electrical conductivity as measured at ordinary temperatures. Cupaloy is also much stronger than copper when hot. Fig. 1 and Table I show the effect of chromium as well as comparisons between Cupaloy and hard drawn copper as to "thermal endurance" and strength when hot.

Table I.—Mechanical Properties of Cupaloy at Elevated Temperature

Estimated total deformation in per cent of original length in 10 yrs.	Permissible stress in Lbs. per sq. in. at 150 deg. C.	
	Copper*	Cupaloy**
0.1	1300	5,800
0.2	2500	10,700
0.4	4500	19,000

* Copper tested after conditioning treatment comprising 15 per cent cold reduction and application of a preliminary load of 12,000 lbs. per sq. in. at 150 deg. C. for 72 hrs.

** Tests were made on standard cold-drawn, temper-hardened Cupaloy bar stock.

Heat treatment alone confers on Cupaloy an interesting and valuable combination of properties. A further happy circumstance is that the heat-treated material combines great ductility with its strength. This means that cold working may be applied to secure still higher strength.

Properties of Cupaloy

The electrical properties of Cupaloy are shown in Table II. The mechanical properties of heat-treated and cold-worked Cupaloy are shown in Table III in comparison with those of copper and a typical structural steel.

Table II.—Electrical Properties of Cupaloy*, Fully Hardened.

Electrical conductivity (per cent of copper)	80-90
Thermal conductivity (per cent of copper)	80-90
Electrical resistivity (microhms, 20°C.)	2.1-1.9
Temperature coefficient of electrical resistivity (per degree C.)	0.3%

* Type 24-47, of the following composition: silver, 0.06-0.12%; chromium, 0.45-0.55%; copper, approximately 99.4%.

Fig. 3 is a graphic demonstration of the high strength of properly treated Cupaloy. A short piece of ½-in. diameter bar stock engraved with an insigne was forced by a hydraulic press against the similarly rounded edge of a piece of ordinary hot-rolled structural steel. A deep indentation and a clearly embossed replica of the insigne were formed in the steel while the Cupaloy was scarcely marked.

The corrosion resistance of Cupaloy has been studied and the results indicate that it is substantially equivalent to copper in this respect.

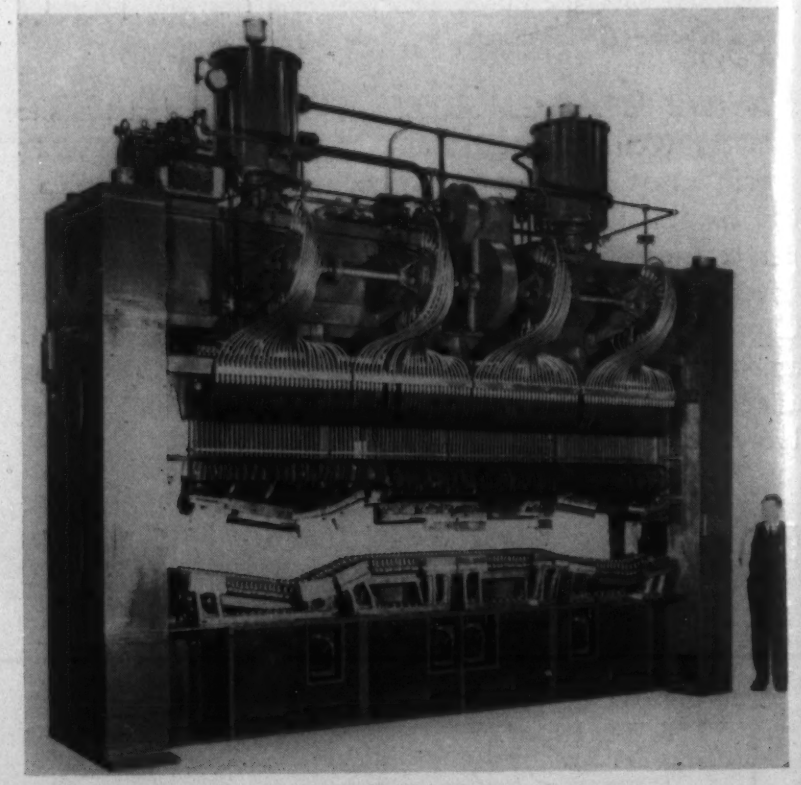


Fig. 4. A Large Spot Welding Press for Fabricating Automobile Frames Using Cupaloy Welding Tips and Massin Cupaloy Anvil Blocks.

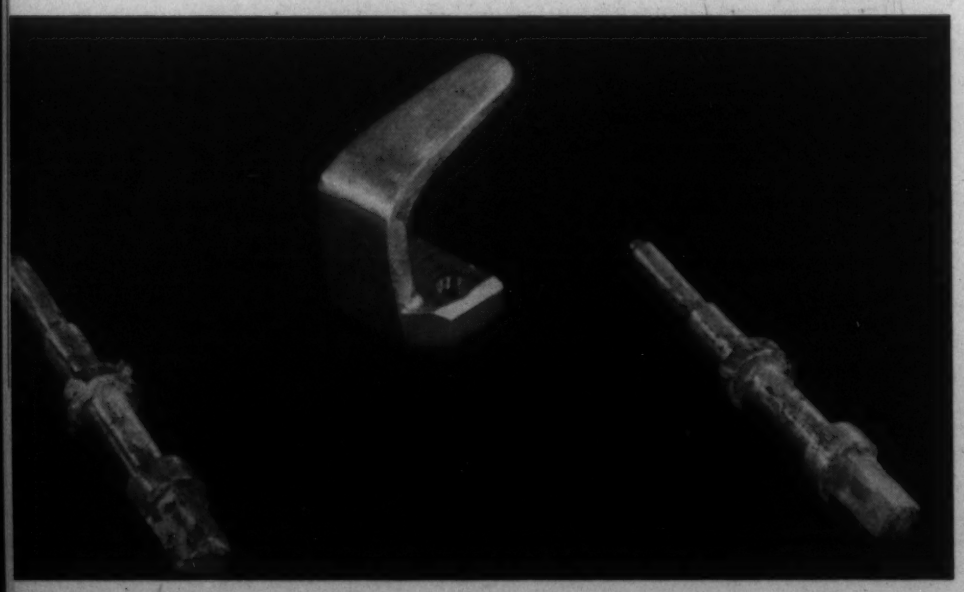


Fig. 5. Cupaloy Parts for Electrical Equipment when High Strength and High Electrical Conductivity are Required.

Applications

The unusual combination ot mechanical, electrical and thermal properties possessed by Cupaloy have made it useful in a variety of ways. In spot and "shot" welding operations advantage is taken of the high electrical conductivity and resistance to the softening effects of elevated temperatures. Fig. 4 shows a large spot-welding press for

Table III.—Mechanical Properties at Normal Temperatures* of Cupaloy, Steel and Copper.

	Cupaloy	Steel, 0.25% C, Hot Rolled	Copper "Tough Pitch" Hard Drawn
Elastic limit, lb. per sq. in. (0.01% permanent elongation)	35,000-40,000	35,000-40,000	4,000- 5,000
Yield strength, lb. per sq. in. (0.2% permanent elongation)	60,000-65,000	40,000-45,000	25,000-30,000
Ultimate tensile strength, lbs. per sq. in.	75,000-80,000	60,000-70,000	45,000-55,000
Elongation, per cent in 2 in.	20-25	25-35	20-15
Reduction of area, per cent	55-65	50-55	70-65
Modulus of elasticity, lbs. per sq. in.	19-20 x 10^6	28-30 x 10^6	17-18 x 10^6
Brinell hardness (3000 kg. load, 10 mm. ball)	140-160	145-155	90-110
Rockwell hardness, "B" Scale	80-90	70-75	50-65
Fatigue strength lb. per sq. in. (100 millions of reversals)	18,000-20,000	30,000-33,000	10,000-12,000

* Data (except hardness and fatigue strength) obtained with standard tensile specimens 2 in. gage length and 0.505 in. diam.

fabricating automobile frames where Cupaloy was used for the welding tips and the massive anvil blocks. Cupaloy parts for electrical equipment where high strength and high electrical conductivity are required are shown in Fig. 5. In a large homopolar generator Cupaloy was used for the slip-rings, which were required to deliver 150,000 amperes. Difficulties created by high centrifugal stresses, abrasion by the brushes and the possibility of abnormal temperatures were successfully overcome. The armature of this machine is shown in Fig. 6. Other fields for the application of Cupaloy are suggested by Table IV.

Table IV.—Applications and Advantages of Cupaloy.

Application	Advantages over other non-ferrous material	Advantages over steel
Welding electrodes	Conductivity, hardness, resistance to softening under heat.	Conductivity, temperature coefficient of resistivity, absence of magnetism, corrosion resistance, heat resistance.
Slip rings	Wear resistance, electrical and heat conductivity.	Conductivity, corrosion resistance, contact resistance.
Cylinder heads for internal combustion engines	Thermal conductivity, hardness, strength at high temperatures.	Thermal conductivity, corrosion resistance.
Transformer terminal studs	Strength, heat resistance, conductivity.	Conductivity, heat resistance, corrosion resistance, lack of magnestism.
Welding machine structural parts	Conductivity, strength.	Conductivity, absence of magnetism, corrosion resistance, machinability.
Springs	High ratio of conductivity to strength.	Conductivity, corrosion resistance, absence of magnetism.
Commutator bars	High thermal endurance and wear resistance.	High thermal and electrical conductivity and current collecting properties; corrosion resistance.
Fuse clips	High thermal endurance and high elastic strength.	High electrical and thermal conductivity and corrosion resistance.

Fig. 6. Cupaloy is Used for Slip-Rings in a Large Homopole Generator, the Armature of Which is Here Shown.

The "Time Capsule"

In choosing a material for the Time Capsule, consideration was given to such factors as strength, ductility, stability, corrosion resistance, ease of fabrication and cost. Had it been feasible to neglect the last-mentioned factor, some one of the high-strength precious-metal alloys might have been chosen. Similarly if attention had been focused on one or the other of the various properties alone, some other materials would have been chosen.

In view of the desire that the Time Capsule be found intact after 5,000 yrs. or so, much thought was given to the corrosion question. The facts that copper implements have come down from antiquity and that there is a large body of successful engineering experience in the use of copper under mildly corrosive conditions, sea-water attack for example, led to the conclusion that a material having corrosion resistance equal to that of copper would have a reasonable chance of surviving such chemical attack as might be expected under the circumstances. Laboratory tests with saline, alkaline and acid media had shown Cupaloy as having almost the same corrosion characteristics as copper. With other requirements such as those of cost, adequacy of physical properties and ease of fabrication satisfactorily met by Cupaloy it seemed that this was a logical choice from an engineering standpoint as well as that of preserving for a distant posterity an example of a unique and useful material of our time.

THE PRODUCTION AND

Industrial Uses of Titanium

—A CORRELATED ABSTRACT

Part II

Concluded from October Issue

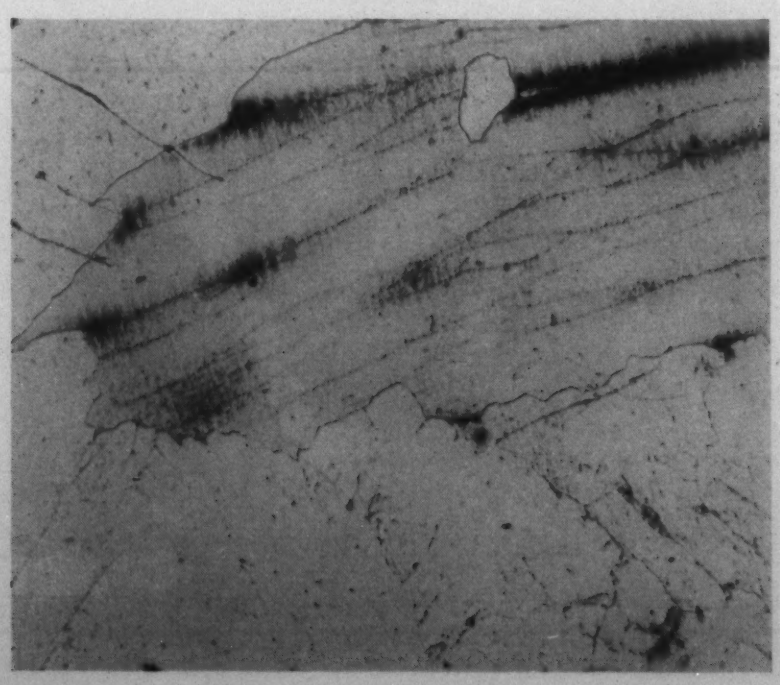
by George F. Comstock

Metallurgist, Titanium Alloy Mfg. Co., Niagara Falls, N. Y.

Manufacture of Pure Titanium

Pure titanium metal, as has been stated, cannot be made by reduction of the ore with aluminum, and, of course, silicon and carbon are also out of the question for this purpose. Calcium or sodium, however, can be used successfully. Kroll in Germany has recently done some very interesting work with titanium metal powder reduced from its oxide by calcium shavings.[21] The titanium powder was sintered in a vacuum and rolled hot into sheets. The metal could not be melted because no crucible material is known with which titanium, above its melting point, will not react. Even the oxides of beryllium, zirconium and thorium were reduced by molten titanium in a vacuum. Kroll made some high-titanium alloys from sintered powders and reported their structures and properties, but no practical applications have so far developed.

Fig. 10. Microstructure of Titanium Metal of About 99 Per Cent Purity, Etched with HF and Magnified 200 Diameters, Showing a Cored Single-Phase Structure Except for Oxide Specks.



Another method for making relatively pure titanium was described recently in METALS AND ALLOYS by P. P. Alexander.[22] This method, involving the reduction of the oxide by calcium hydride, produced titanium in powder form, which could not be freed completely from hydrogen. The method was used also for making pure copper-titanium alloys.

Table III.—Hardness and Conductivity of Two Copper Alloy Castings after Various Treatments.

Alloy Content, Per Cent	Heat Treatment	Rockwell E Hardness	Electrical Conductivity, Per Cent
2.04 Be	None, as cast	90	22.0
	Quenched from 1475° F.	74	18.8
	Tempered 5 hrs. at 700° F.	118	32.8
	Tempered 35 hrs. at 700° F.	115	36.8
0.87 Ti and 0.35 Si	None, as cast	80	27.3
	Quenched from 1650° F.	49	26.9
	Tempered 24 hrs. at 850° F.	85	40.1
	Tempered 48 hrs., 850 to 950° F.	87	46.5
	Tempered 24 hrs. at 1000° F.	79	66.2

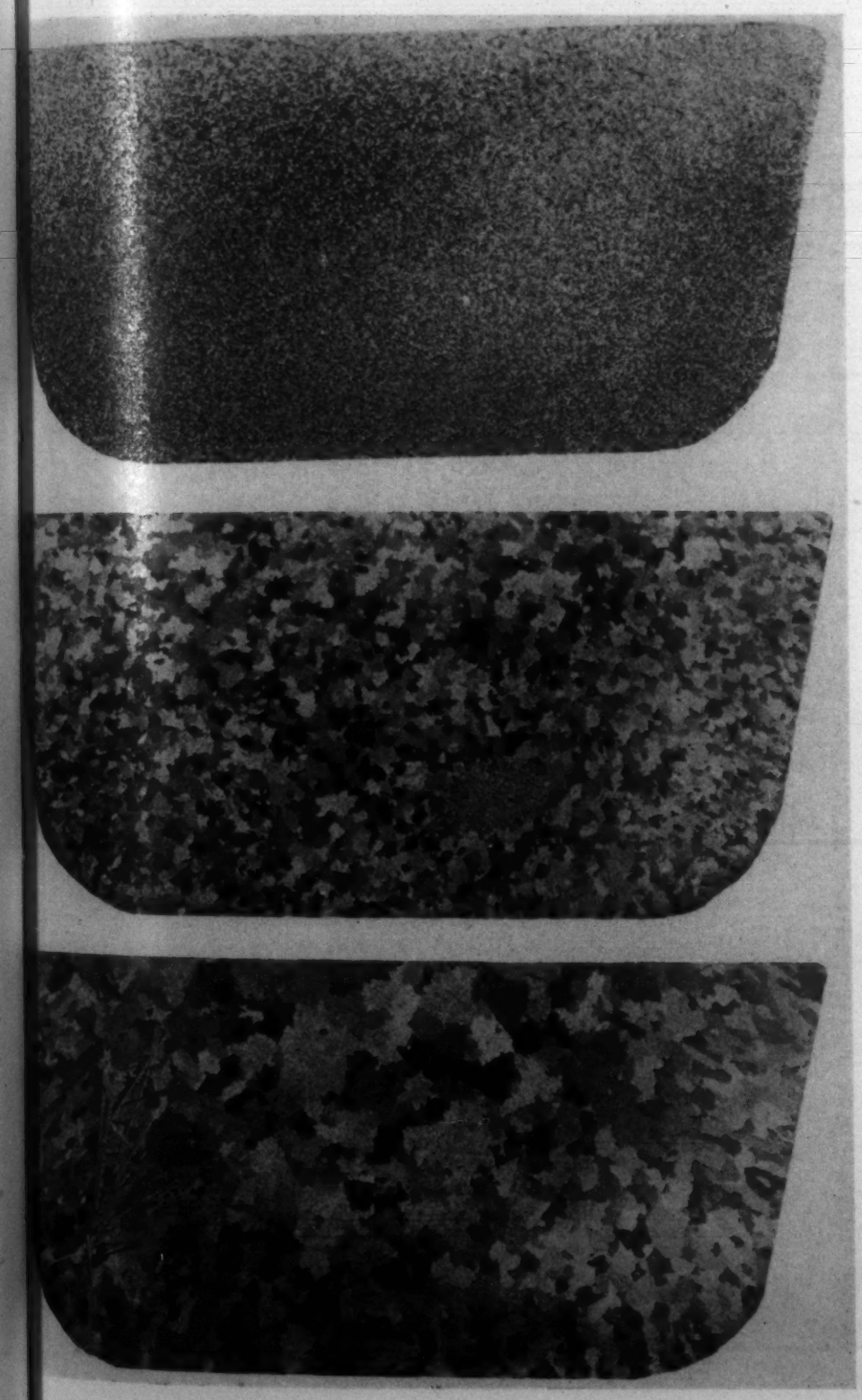
Still another method for making pure titanium metal is by reduction of the chloride with sodium in a closed vessel under pressure. This process was described by Hunter,[23] who adapted it from the work of some German experimenters,[24] and gives pure coherent metal very suitable for making alloys. Its microstructure is shown in Fig. 10. It has been produced commercially in fairly large amounts and used in copper, nickel, aluminum and mercury. Mercury treated with metallic titanium has been found to corrode mercury boilers less severely so that replacement of the steel shell is not required so soon.

Titanium in Non-Ferrous Alloys

Copper can be hardened with titanium in about the same fashion as with beryllium, but not so intensely.[25] The reason for the age-hardenability is evident from the slope of the alpha solid solution curve on the equilibrium diagram of Hensel and Larsen.[26] With either titanium or beryllium the electrical conductivity as well as the hardness are increased by "tempering" after quenching, as indicated by Table III, taken in part from an article by the author in METALS AND ALLOYS.[27]

In the tempering treatment of these alloys a compound is precipitated from solid solution in such a finely divided form that the resistance to deformation becomes much greater, while at the same time the higher purity of the solid solution improves the conductivity. With titanium, the best quenching temperature is generally 1650 deg. F. and tempering is carried out at about 850 deg. F. for 24 hrs. For best results silicon should be present in the alloy with titanium, a good combination being about 0.8 per cent titanium and 0.35 per cent silicon. This alloy in the form of properly heat-treated castings will have about 45 per cent conductivity, 85 Brinell hardness, and 25,000 lbs. per sq. in. yield point, which is much stronger than pure copper castings and at the same time more electrically-conducting than other copper alloys of comparable strength.

Fig. 11. Sections of Aluminum Alloy Ingots, Made in the Same Way Except for Titanium Additions. Etched with HF and HCl and slightly reduced from an original of 2 diameters. The coarse grained ingot contained 0.015 per cent Ti, the middle one 0.114 per cent, and the fine-grained one 0.14 per cent. (From Metal Progress, *Vol. 27, Jan., 1935, p. 41.)*



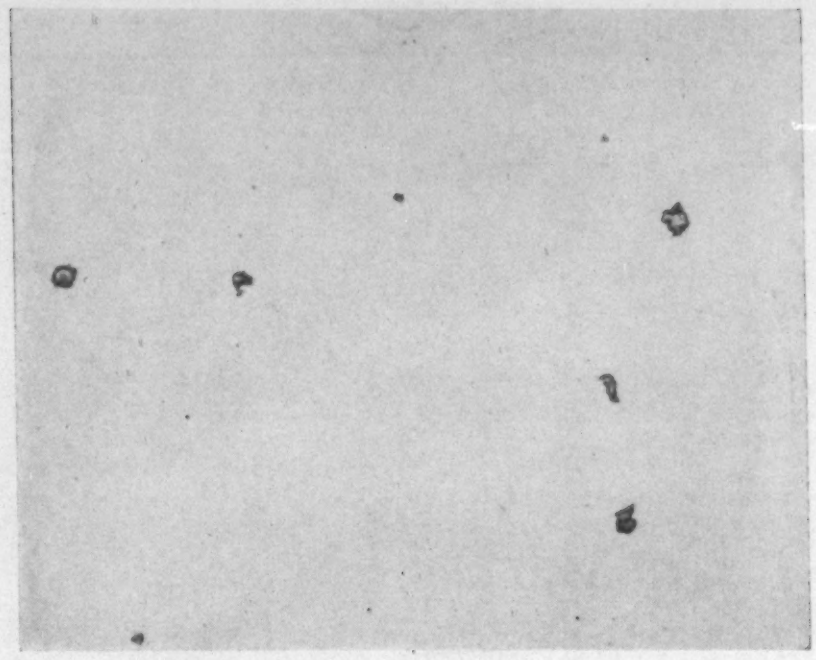


Fig. 12. Typical Crystals of Titanium Cyanonitride in a Chromium Steel Containing 0.135 Per Cent Titanium. Unetched and magnified 500 diameters.

Nickel and its alloys are also hardened by titanium in the same way.[28] Some recent patents[29] disclose a new permanent magnet steel containing about 16 per cent nickel, 28 per cent cobalt and 11 per cent titanium, which after annealing at 1250 deg. F., has about double the coercive force of Alnico, or nearly five times as much as the cobalt-chromium-tungsten permanent magnet steel, but with slightly less residual induction. The properties of some of these strongly magnetic alloys are presented for comparison in Table IV. The chief use of titanium in nickel, however, is as a deoxidizer or degasifier in welding. It has been found to be almost indispensable for making sound nickel welds, and is widely used in the form of an alloy powder in nickel welding-rod coatings.[30]

Titanium has a different function in aluminum alloys and is used in this way more than is realized, since one of the largest producers has been quietly incorporating titanium in some of its products for a long time. Here the chief advantage is grain refinement, and as a result of the finer grain of aluminum castings containing titanium the strength, ductility, and soundness are all improved.[31] The grain sizes obtained in castings of the same size, all poured at the same temperature from an aluminum alloy with 6 per cent copper, 1.2 per cent silicon and various amounts of titanium are shown in Fig. 11.

Titanium forms a compound with aluminum that separates from a cooling molten alloy in fine crystals before the rest of the alloy freezes,[32] and the fine crystals of the titanium compound provide nuclei to encourage the starting of more grains of the aluminum alloy, when it freezes, in a given volume. Then none of those grains can grow so large before being stopped by others. It takes only about 0.1 to 0.2 per cent of titanium to refine the grain enough for an increase of 15 or 20 per cent in strength. This titanium content is easily obtained from an addition of about 2½ lbs. per hundred of a master alloy of aluminum containing 5 or 6 per cent titanium. A higher-grade master alloy can be made, but it would be too difficult to dissolve in aluminum alloy melts.

Titanium Alloy Steels

As an alloying element in steel, titanium suffers from

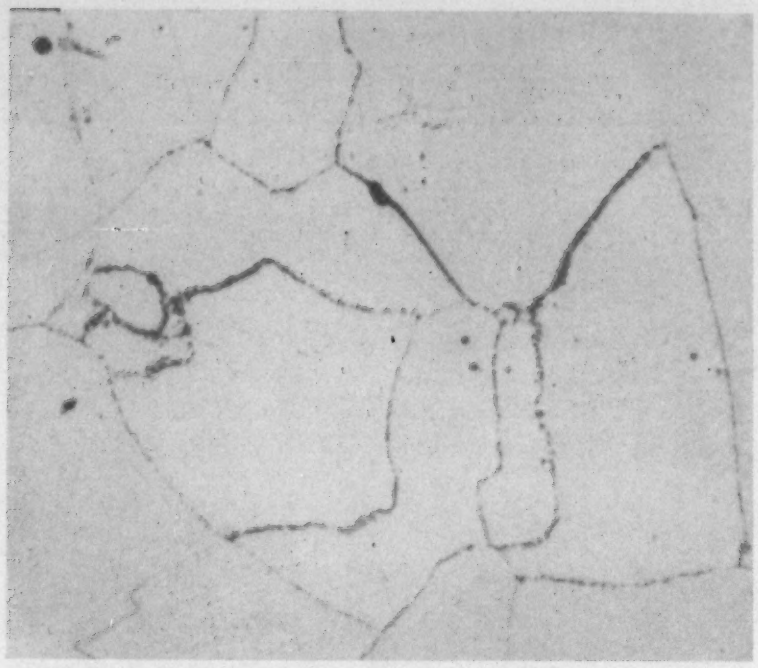


Fig. 13. Carbide Precipitated at Grain Boundaries of a Steel Bar Containing 0.06 Per Cent C, 0.34 Mn, 0.28 Si, 17.31 Cr and 9.12 Ni, Quenched from 1950 Deg. F., Tempered 16 Hrs. at 1200 Deg. F. and Cooled in Furnace. Etched with aqua regia in glycerine and magnified 1000 diameters.

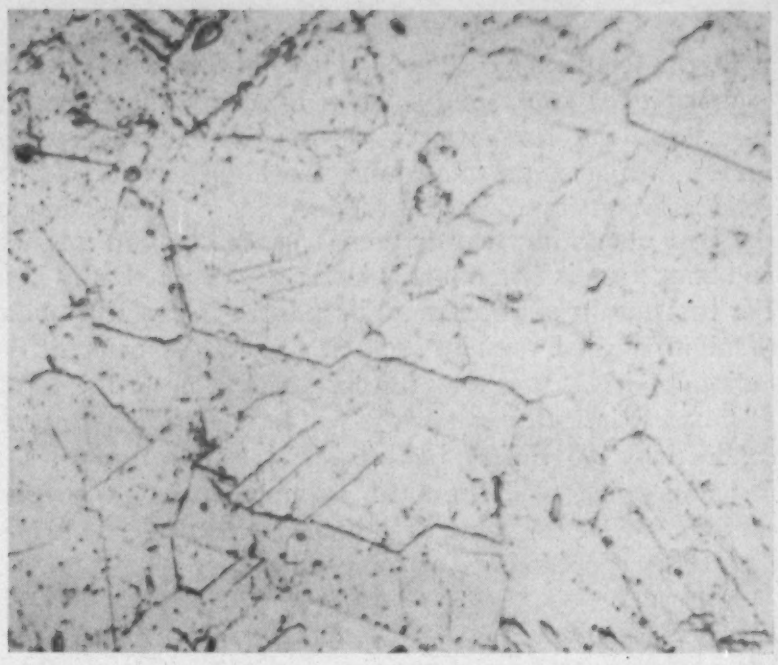


Fig. 14. Finer Structure, with Scattered Carbide Specks, in a Steel Bar Containing 0.07 Per Cent C, 0.59 Mn, 0.47 Si, 18.08 Cr., 9.12 Ni and 0.34 Ti. Heat-treated, etched and magnified the same as Fig. 13.

the disadvantage of being too good a deoxidizer. This means that it is oxidized so readily at steel-making temperatures, that it is the most difficult element to recover as a residual alloy in the finished steel. With open hearth melting practice it is virtually impossible to get more than about 0.25 per cent titanium content, and basic electric practice is required for making alloy steels with higher titanium.

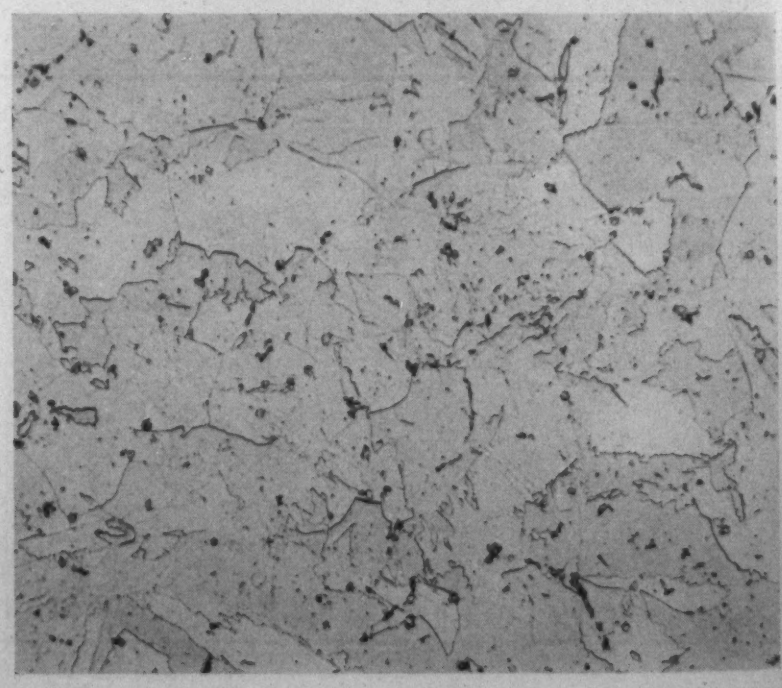
The presence of titanium to any appreciable extent in steel is nearly always evidenced by small pink or orange angular crystals of titanium cyanonitride, which can be seen with the microscope on a properly polished section.[33] The

Table IV.—Properties of Permanent Magnet Steels.
(Data taken from 1936 A.S.M. Handbook and U. S. Patents).

Name	Composition, Per Cent								Residual Induction	Coercive Force	Product $\times 10^{-6}$
	C	Mn	Cr	W	Co	Ni	Al	Ti			
Chromium	1.00	0.35	6.00	...	...	...	...	...	9000	72	0.65
Tungsten	0.70	0.30	0.20	5.5	...	...	...	...	10000	65	0.65
Co-W	0.85	0.50	3.5	8.7	17.0	...	...	...	9000	165	1.5
High Cobalt	0.90	0.60	4.5	5.5	38.0	...	...	...	9700	235	2.3
Alnico	...	...	...	...	7.0	27.0	11.0	0.5	9000	400	3.6
Mishima	...	...	...	...	...	30.0	12.0	...	9500	430	4.1
Honda	...	...	...	...	28.0	16.0	...	11.0	7500	830	6.2

Fig. 15. Martensitic Structure of a Steel Casting Containing 0.23 Per Cent C, 0.59 Mn, 0.30 Si, 5.67 Cr and 0.51 Mo, Normalized 5 Hrs. at 1650 Deg. F. and Air-Cooled. Etched with nitric acid and magnified 200 diameters.

Fig. 16. Ferritic Structure with Fine Titanium Cyanonitride Crystals in a Steel Casting Containing 0.11 Per Cent C, 0.52 Mn, 0.68 Si, 5.44 Cr, 0.45 Mo and 0.67 Ti, Heated 5 Hrs. at 1950 Deg. F., Quenched in Water, Tempered 16 Hrs. at 1150 Deg. F. and Air-Cooled. Etched with aqua regia in glycerine and magnified 200 diameters.



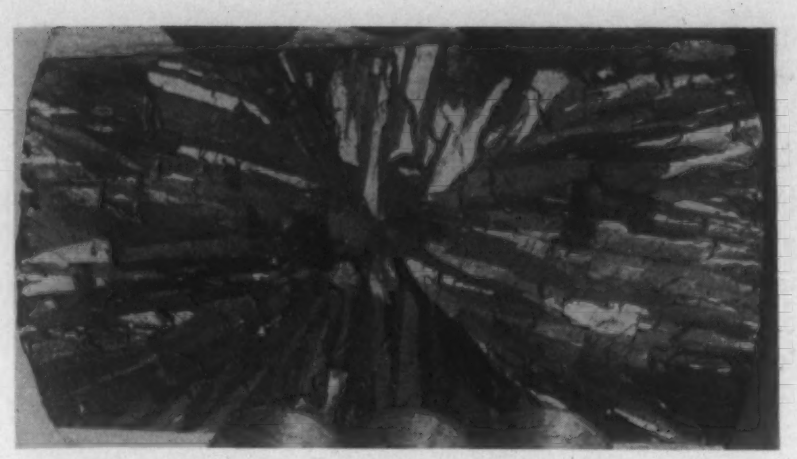


Fig. 17. Fracture of a 24 Per Cent Chromium-Iron Ingot, Actual Size.

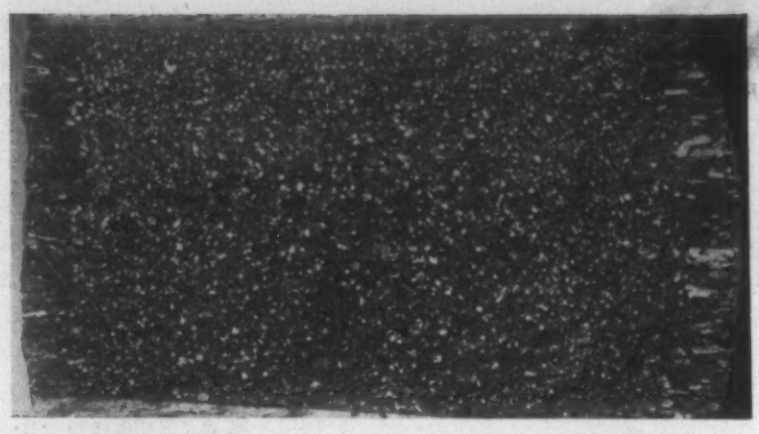


Fig. 18. Actual Size Fracture of Another 24 Per Cent Chromium-Iron Ingot. This was made in the same way as Fig. 17 except for the addition of 1.8 per cent titanium cyanonitride, giving 0.138 per cent N and 0.053 per cent Ti.

appearance of these crystals is illustrated in Fig. 12 at a magnification of 500 diameters.

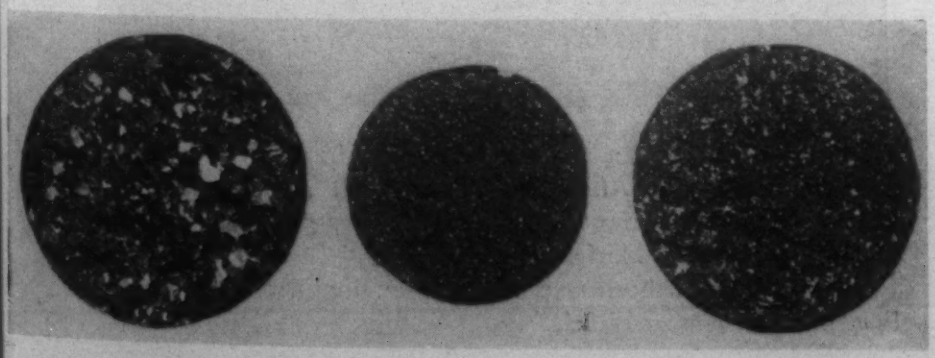
In producing true titanium alloy steels, thorough deoxidation must be effected before the titanium is added, the slag must be fluid and free from reducible oxides, and the steel should be tapped soon after adding the titanium.[8] With these precautions effectively carried out in basic electric practice, these titanium alloy steels can be produced consistently.

At present the chief purpose in using titanium as an alloying element in steel is to remove the carbon from an active form to the relatively inert combination with titanium as titanium carbide. By this means such troubles as intercrystalline corrosion of stainless steel caused by the formation of chromium carbide are prevented.[34] The microstructures of two 18-8 stainless steels, with and without titanium, but both heat treated alike, are shown in Figs. 13 and 14. Carbides are shown segregated at the grain boundaries of the non-titanium steel, while in the titanium steel the titanium carbide is scattered within the grains where it is practically harmless.

Similarly the air-hardening embrittlement of chromium steels, caused by the formation of martensite, is prevented by titanium and these alloy steels can be welded and cooled rapidly without losing their machinability or ductility.[35]

Fig. 19. Tensile Fractures of 25 Per Cent Chromium-Iron Alloy Forgings, Heated 12 Hrs. at 2150 Deg. F. Magnified about 2.4 diameters. At the left is the untreated alloy, in the center the alloy treated with 3.8 per cent titanium cyanonitride and at the right the alloy made with 17 per cent high-nitrogen ferrochromium. Properties of the alloys so prepared were as follows:

	Untreated Alloy	*Alloy treated with 3.8% Titanium Cyanonitride.*	*Alloy made with 17% High-Nitrogen Ferro-Chromium*
Carbon	0.12	0.17	0.15 Per Cent
Nitrogen	0.081	0.234	0.272 Per Cent
Yield Point	52,400	65,800	70,500 Lbs. per Sq. In.
Tensile Strength	66,400	94,300	104,200 Lbs. per Sq. In.
Elongation	4.5	29.5	7.0 Per Cent
Reduction of Area	3.9	35.9	12.8 Per Cent



Microstructures of heat-treated 5 per cent chromium steel castings, with and without titanium, are illustrated in Figs. 15 and 16, showing the martensitic structure of the non-titanium steel, and the ferritic non-hardening structure of the other in which all the carbon is combined as inactive titanium carbide.

Titanium must be present in these steels to the extent of about six times the carbon content to be effective in this way, and must be given time to combine with the carbon before the finished steel becomes too cold. Titanium is either more effective or less expensive than other alloy additions that have been proposed for this purpose of carbide control.

Another Field for Ti

Another field for titanium as an alloying element in steel is for hardening and strengthening the austenitic highly-alloyed steels that are not hardenable by heat-treatment in the usual way.[36] This generally requires titanium contents of several per cent or more, and involves a tempering or aging treatment such as is used for hardening titanium-copper. The possibility of age-hardening in this way is evident from the slope of the solubility line in the iron-titanium diagram,[44] which resembles in a general way the copper-titanium diagram.[26] This iron-titanium diagram has not been altered materially from the form proposed in 1914 by Lamort,[37] who used only quite impure materials in his investigation. The only change made more recently is the addition of the solid solubility line according to the results reported in 1932 by Seljesater and Rogers.[38]

Tensile strengths as high as 150,000 to 200,000 lbs. per sq. in. have been attained in titanium stainless steels hardened by precipitation of a titanium compound in tempering, and with reasonable ductility.[39] Nickel is probably an essential ingredient of alloy steels that can be age-hardened by titanium, and more will probably be heard of this process in future years. So far as is now known, titanium is unique in possessing this ability to confer such marked age-hardening properties on nickel alloys.[28]

A Recent Development

A very recent development with titanium in alloy steels is the use of titanium cyanonitride as a source of nitrogen for refining the grain and improving the properties of high chromium steels. The advantages of nitrogen in such steels have been known for some time,[40] and it seems to be distinctly easier to secure these benefits without trouble from

unsoundness or porosity when the nitrogen is added as the titanium compound.[41] Typical fractures of 24 per cent chromium irons, with and without the addition of titanium cyanonitride and cast to the same size from the same temperature, may be compared in Figs. 17 and 18.

The chromium-iron readily absorbs the nitrogen supplied as titanium cyanonitride, leaving the titanium to deoxidize and clean the metal, so that sound castings of fine grain size may be made even of the high-chromium irons, which normally are apt to be very coarse-grained and brittle. Fig. 19 illustrates some results of the treatment of these alloys with nitrogen in various ways.

Although more might be written regarding other miscellaneous applications of titanium, such as the use of the carbide in sintered carbide tools,[42] and of the oxide in enamels, glazes, etc.,[43] enough ground has probably been covered in describing the more important metallurgical applications to give an idea of the wide field of usefulness for this no-longer "rare" element.

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Large Freighter with Nickel-Lined Holds

A novel ship, built in a novel way for a novel service, has recently been placed in operation on the Great Lakes. She is the twin screw Diesel ship "Dolomite IV," 300 ft. long, with a 43-ft. beam and gross tonnage of 5,500, and is built to ocean classifications under Lloyd's rating.

The two most interesting features of this unusual craft are her all-welded construction, and her holds, which are lined with 16-gage nickel sheet. Approximately 40 miles of welding were required to complete her hull—there is not a rivet in the whole construction. In lining the five holds 60,000 lbs. of nickel sheet was used, for which 1200 lbs. of pure nickel welding wire was required; the sheets were first tack-welded and then seam welded. Dolomite IV, built by the Dolomite Marine Corp., is believed to be the largest all-welded vessel in Great Lake's service and to be the first large freight ship anywhere featuring nickel cargo tanks.

The nickel-lined hold construction permits not only the transport of caustic solutions or other corrosive chemicals, but also rapid cleaning of the holds when the corrosive cargo is to be unloaded and replaced with dry cargo such as grain. So far the ship, travelling between Great Lakes ports, has carried kerosene, gasoline and grain. After the close of fall navigation on the Lakes, she will haul caustic soda and other cargoes between Gulf of Mexico ports and Norfolk, Va.

The pumps and the linings of the 8-in. liquid cargo discharge lines are also of pure nickel.

Honesty in the Foundry Business

Part I

by Harold J. Roast

Vice President,
Canadian Bronze Co., Ltd.
Montreal, Canada

This article is based largely on an address delivered before the Philadelphia Chapter of the American Foundrymen's Association. The author is well-known to foundrymen in general and to those in the non-ferrous field in particular. We are indebted to Dr. G. H. Clamer, one of our editorial advisory board, who arranged for our receiving it.—The Editors.

IT MIGHT BE SAID that the subject chosen for this discussion has certainly no merit from the point of view of novelty, to which I reply that this is open to question, depending on time and place.

Some Definitions

Further it is fundamental that old truths are always worthy of restatement. First of all, let us be clear as to the definition of the words we use. Honesty is described as the "character or quality of being honest," and on looking up "honest" we find "fair and candid in dealing with others," "free from fraud," "trustworthy," "one who is honest in the ordinary sense acts, or is always disposed to act, with careful regard for the rights of others, *especially* in the matter of business"; "one who is 'honorable' scrupulously observes the dictates of a personal honor that is higher than any demands of mercantile law or public opinion and will do nothing unworthy of his own inherent nobility of soul."

To quote further, "the honorable man will not take an unfair advantage that would be allowed him" (that is by usage). "One who is honest in the highest and fullest sense is scrupulously careful to adhere to all known truth and right even in thought." "In this sense 'honest' differs from 'honorable' as having regard to absolute truth and right rather than even to the highest personal honor."

It will be seen, therefore, that this word honesty is one of the very powerful words of our language.

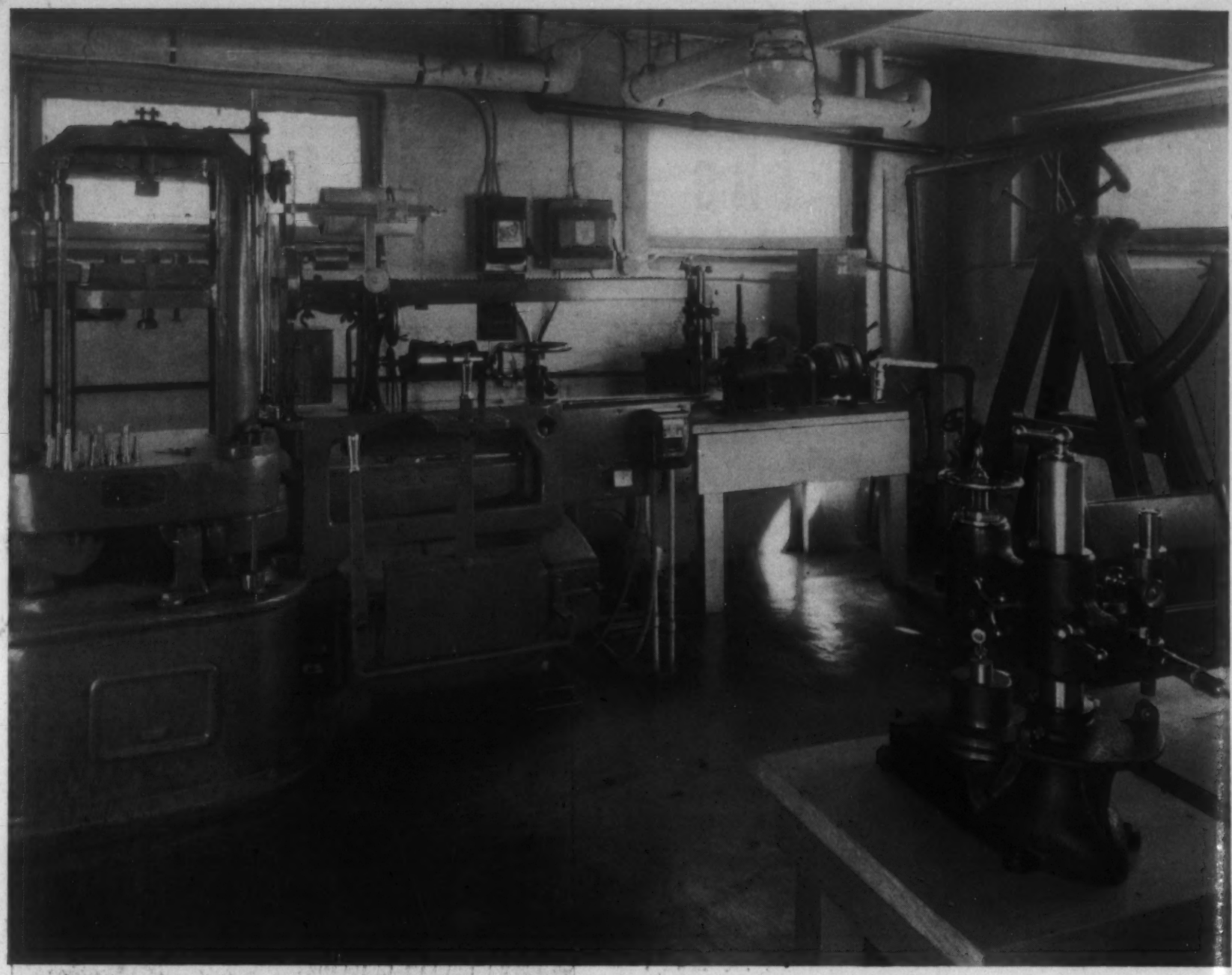
Let us turn for a moment to the antonyms of honesty, for antonyms often act as a searchlight on word meanings. We may be indifferent to the right word and yet shrink horribly from its antonym. Under the antonyms of honest we find: Deceitful, false, fraudulent, lying, independable, cheat. The last two words are particularly obnoxious, for we all like to have it said of us, "You can depend on him" and to justify the opprobrium "cheat" is bad indeed. Your

Symbolic Picture of the Foundryman (Courtesy: Warner & Swasey Co., Cleveland)

own great Washington, the anniversary of whose birthday you always celebrate, wrote: "I hope I shall always possess firmness and virtue enough to maintain what I consider the most enviable of all titles, the character of an honest man."

Meaning of "Foundry Business"

The remainder of the title of this address, "the foundry business," is meant to include manufacturer and purchaser, seller and customer, for all form part of the foundry industry. The dictionary throws an interesting and, in these days even an amusing light, on the definition of "Business." It is "what one follows regularly and for profit," whereas



Physical Testing in the Laboratory of the Canadian Bronze Co.

an "occupation is what a person is engaged in, whether for profit or not." In these times I fear many of us are engaged therefore not in "business" but "occupations."

Having cleared the air as to the meaning of the title of this discussion, let us become specific, taking as an example a fairly large foundry employing chemists, metallurgists, etc.; the smaller foundry will find its departments included in these.

There is the boy who stamps the castings as to heat number, or other markings. This entails accuracy, it is true, but still more honesty. If the boy's idea of a day's work is to do as little as possible with as litle care as possible, then he is not giving "an honest day's work." A mistake in the numbering of the casting may start a train of incorrect reasoning that may have costly results. There is another side to this, namely, where a foreman may tell the boy to mark a casting in a manner to deceive some individual such as an inspector or other person. Such an act may have far-reaching results, but worst of all it may turn an upright boy into a cheat.

Then there is the man who weighs out the various mixes to the melting room. How important here that such a man be trustworthy, that he follow the precept of the Mahommedan Koran to: "Give full measure out, and weigh with a right balance." The remark to such a one, "Be careful of the Tin but don't forget its 50c a pound," is not by the way of building up the man's integrity. One cannot expect anyone to be dishonest upon suggestion and revert to honesty for the rest of the day.

Those whose duty it is to take the pouring temperature of the various metals have a job that depends for its usefulness entirely on the faithfulness of the employee. Immediately the temperature is indicated by the pyrometer, time and cooling rate come into play and all the evidence is wiped out. The record must be made by one who is worthy.

Melting and Molding

The operation of melting the metal is an all-important one and we all know the significance of trifles such as charging solid metal first and borings later to the molten metal or the loading of a crucible so that no metal sticks above it in the furnace atmosphere, or the removal of a high zinc alloy as soon as the white flare of volatilized zinc oxide is noticed. All these things are by nature fugacious and therefore not to be checked by the occasional visit of the foreman. The inherent honesty of the melter is the company's only protection.

Molding is still an art in many cases and therefore depends primarily on the individual capacity, but whether this capacity is always used depends on the earnestness of the molder, his interest in his work, his faithfulness to carry

out the job to the best of his ability. A box is closed and ready to pour. Were all the fillets properly made? Was the ramming too hard or too soft? Did the box fit exactly when closed, or was there any disturbance of the sand due to poor alignment? Did the pattern draw right or, if patching was needed, was it well done? The answers to all these questions depend on the man himself, his honesty. Let it be said of him as in "The Building of the Ship" by Longfellow:

"For his heart was in his work, and the heart
Giveth grace unto every Art."

The same applies to coremakers—a core may seem dry, but is it? The man himself is the one who knows most about it. He may have hurried the drying, he may say to *himself*: "Oh, that's good enough" and to the foreman "Yes, it's dry as a bone." The satisfactoriness of his cores depends, assuming that he knows his trade, on his trustworthiness.

The Foreman and Superintendent

The foreman in a company occupies an analogous position to a sergeant major in the army. Upon his shoulders rests the responsibility for organized effort of the rank and file, and he is the channel through which the superintendent informs himself of the general condition of the foundry.

If the superintendent comes along and says to a foreman, "How is everything today Bill?" and Bill, standing in front of an important scrap casting, says "Fine," then the road may be blocked for the proper correction of the cause of the faulty casting, and in the eyes of the men in general an impetus is given to the stock phrase "We got away with it." The same applies to the ancient custom of hastily throwing the scrap casting back into the furnace before there has been a chance of *recording* it as scrap.

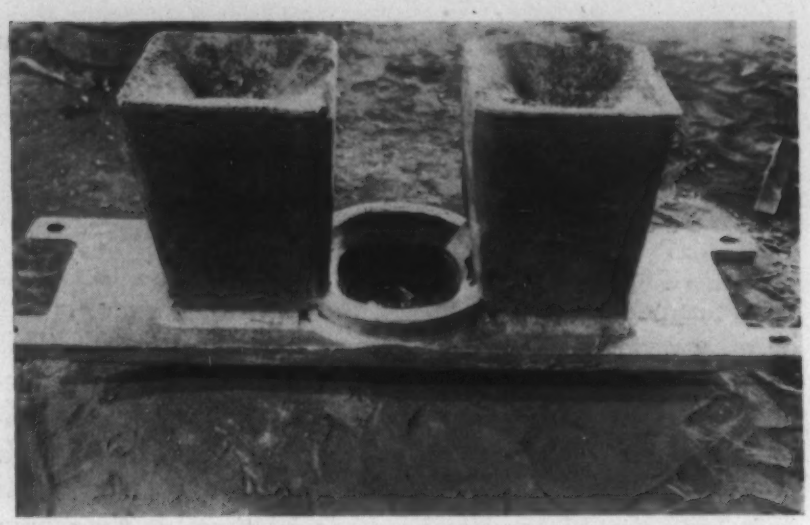
The superintendent is responsible *TO* the management *FOR* the men and their product. The management depend on his integrity as to the picture of operation as presented to them. If he covers up shop problems, both labor and manufacturing, because his own reputation is adversely affected thereby, his presentation is untrue and therefore misleading and hence dishonest. There must be no accumulation of satisfactory test bars to be trotted out whenever an inspector calls for a representative bar of a currently made casting. The, I believe, rare, dishonest practice of insisting on a rebate of men's wages if they are to continue on their job, the same to be payable to the superintendent, has only to be mentioned to be condemned.

All the positions mentioned so far are under the control of the superintendent and on him therefore rests the obligation to hold high the standard of honorable dealing. Let him remember that as stated in the Bhagarad-Gita translation from the Hindu:

"Whoso performeth—diligent—content
The work allotted him, whate'er it be
Lays hold on perfectness."

Chemists, Metallurgists and Inspectors

When we go into the technical department we find the chemists. Many are the temptations of the laboratory. A sample is being run for, say its zinc content, the operator's hand slips on the burette tap and the titration is overdone. How easy to say "I think that 10 ccs. would have been correct," and then the next step the putting down on the report card of the result based on this 10 ccs. *as* being in truth the accurate figure. Science as art is after the truth and any result that is intentionally reported as accurate when it is known not so to be is a lie.



A Manganese Bronze Casting Showing Risers Needed to Make it "Honestly Good All the Way Through"

Then again there is the inspector who wants analyses altered to pass the specification; this is so obviously dishonorable that it needs no more than mention. Yet the temptation to the young chemist is great, especially when urged so to do by the foreman or superintendent. It takes real courage for an employee or the company itself to risk the loss of a large weight of castings rather than "adjust" a simple chemical or physical certificate. Yet in the long run that concern which adheres to an honorable attitude despite temporary losses will establish the better business.

The metallurgist has to some extent similar difficulties to the chemist, but, because he is not so secluded, it is perhaps a fact that the temptations are not quite so great or so frequent. The work of the metallurgist is more in the open; the whole foundry can see the results of what he does. Nevertheless, let us take a case of a large casting made under his direction; it is found to have shrinkage spots by the risers, because the pouring temperature was incorrect. Who shall the metallurgist blame? He himself who decided on the pouring temperature or the molder who, he might say, made the risers wrongly. Possibly only the metallurgist knew that the trouble was caused by the wrong temperature, yet in common fairness he must take the blame and not seek to transfer it to other shoulders.

A Box Used for Making a Manganese Bronze Casting

Let the chemist and metallurgist remember the reward of work as stated by Carlyle: "For work is the grand cure for all the maladies and miseries that ever beset mankind,—honest work which you intend getting done."

Inspection

Let us now turn to the matter of inspection. This should be welcomed by both supplier and purchaser alike, but to be of any value it must be unbiased and independent. This applies equally to inspectors inside or outside the producing company. If a professional inspection company is employed and paid for certain independent tests upon which to base their acceptance or rejection of the product, then such tests should actually be made by them at their own charges, for as is also stated in the Bhagarad-Gita translation it is better to:

> "Do thine allotted task
> Work is more excellent than idleness."

It is not honorable to take the figures provided by the manufacturer, no matter how high a reputation he may enjoy, unless in those special cases where it is so understood by all three parties concerned, namely, the buyer, the inspection company, and the supplier.

The uprightness of the inspection company is called upon in the matter of unfair discrimination as between two or more manufacturers whereby a lower standard is accepted by the concern specially favored, to the detriment of those actually maintaining the standard specified.

Regarding this matter of inspection, I do not mean to imply that it must be mechanical, using only the actual letter of the specification, but rather that, so that it be honestly done, there may be considerable latitude on the part of the inspector if only the manufacturer be perfectly frank and any adjustments be made with the full agreement of all interested.

The works doctor is now an acknowledged institution; here again we have one whose work is largely done by and unto himself, that is, decisions as to treatment, employment or otherwise. How important that he be a man of the highest integrity and honorable to a degree. For the doctor to gain the confidence of the employees, and he will never be a success unless he does, he must be a man whom the men respect and in fact if he is such a man, this respect will soon merge into admiration.

In Operation

Over all these activities we may expect to have a vice-president of operation. On him lies the responsibility in large measure for setting the standard of honesty high and this not by memos or words but by example. Nothing is really believed in until it is embodied in the daily life of men. This man is the one to whom the president looks for presentation of the whole picture of the manufacturing end of the business and unless his reports are unbiased and factual, unless the president can have faith in them because he has faith in the man presenting them, many an injustice may be done to individuals on the one hand or the company on the other. It is for him to check up as far as possible in order to see that justice is done to all with malice toward none.

The Sales Division

Let us turn from the operating end to the sales division. With this may be considered such positions as service engineers. These men meet the actual users of the product and theirs is often a difficult position as between buyer and seller. If, however, the service engineer sticks to the facts and what he honestly believes to be the truth concerning them, no serious contretemps is likely to develop. To lie in an attempt to cover up a defect or mistake will ultimately bring serious trouble on the shoulders of the very person or organization that it was intended to protect, while at the same time lowering the reputation of the service engineer for candid dealing.

Salesmen, or anyone temporarily in the role of salesman, have in their keeping the reputation of the company they represent. Such men must above all else be men of integrity. They must not accept an order covered by a specification they do not intend to have filled. How easy when the purchaser wants a reduction in price for the same quality to give him the lower price with the unexpressed intention of giving him a less high class product; to promise delivery at a date he has every reason to believe his company cannot fulfill, just to help secure the order; to endeavor to secure the price submitted by his competitor with the view of bidding *just* below it.

All these practices come under the antonyms of honesty, mentioned at the beginning of this discussion, namely, deceit, fraud and cheating and all involve lying, either by speech or suggestion.

Let us believe in probity and bear in mind what was said to one who remarked "I do not believe that there is an honest man in the world" to which another replied "It is impossible that any one man should know all the world, but quite possible that one may know himself."

Heading the sales department is the vice-president in charge of sales. Here again it is by precept and still more by example that he must discharge his responsibilities of inculcating fair dealing and upright trading. The giving of presents to buyers is a custom as unethical as it is unprincipled. *(To be Concluded)*